Evidence for Electroweak Production of $W^{\pm}W^{\pm}jj$ in pp Collisions at $\sqrt{s} = 8$ TeV with the ATLAS Detector

G. Aad *et al.**
(ATLAS Collaboration)
(Received 23 May 2014; published 3 October 2014)

This Letter presents the first study of $W^{\pm}W^{\pm}jj$, same-electric-charge diboson production in association with two jets, using 20.3 fb^{-1} of proton-proton collision data at $\sqrt{s} = 8$ TeV recorded by the ATLAS detector at the Large Hadron Collider. Events with two reconstructed same-charge leptons ($e^{\pm}e^{\pm}$, $e^{\pm}\mu^{\pm}$, and $\mu^{\pm}\mu^{\pm}$) and two or more jets are analyzed. Production cross sections are measured in two fiducial regions, with different sensitivities to the electroweak and strong production mechanisms. First evidence for $W^{\pm}W^{\pm}jj$ production and electroweak-only $W^{\pm}W^{\pm}jj$ production is observed with a significance of 4.5 and 3.6 standard deviations, respectively. The measured production cross sections are in agreement with standard model predictions. Limits at 95% confidence level are set on anomalous quartic gauge couplings.

DOI: 10.1103/PhysRevLett.113.141803 PACS numbers: 14.70.Fm, 12.60.Cn, 13.38.Be, 13.85.Fb

The scattering of two massive vector bosons (VBS), $VV \to VV$ with $V = W$ or Z, is a key process to probe the nature of electroweak symmetry breaking [1,2]. In the absence of a standard model (SM) Higgs boson, the longitudinally polarized VBS amplitude increases as a function of the center-of-mass energy $\sqrt{s}$ and violates unitarity at energies around 1 TeV [3–5]. The recent discovery of a 125 GeV SM-like Higgs boson at the Large Hadron Collider (LHC) [6,7] provides a plausible explanation for the mechanism that unitarizes this process. However, many physics scenarios predict enhancements in VBS either from additional resonances or if the observed SM-like Higgs boson only partially unitarizes this amplitude [8,9]. There is no previous evidence for a process involving a $VVVV$ vertex.

At hadron colliders VBS can be idealized as an interaction of gauge bosons radiated from initial state quarks yielding a final state with two bosons and two jets ($VVjj$) in a purely electroweak process [10]. VBS diagrams are not separately gauge invariant and must be studied in conjunction with additional Feynman graphs leading to the same $VVjj$ final state [11]. Two classes of physical processes give rise to $VVjj$ final states. The first process, which includes VBS contributions, involves exclusively weak interactions at Born level (of order α_{EW}^4 without considering the boson decay, where α_{EW} is the electroweak force coupling constant) and is referred to as electroweak production. The second process involves both the strong and electroweak interactions at Born level (of order $\alpha_s^2\alpha_{\mathrm{EW}}^2$, where α_s is the strong force coupling constant) and is referred to as strong production. In the case of same-electric-charge WW production ($W^{\pm}W^{\pm}jj$), the strong production cross section does not dominate the electroweak cross section, making this channel an ideal choice for initial studies on VBS.

This Letter presents the first evidence for electroweak $W^{\pm}W^{\pm}jj$ production, where both W bosons decay leptonically ($W^{\pm} \to \ell^{\pm}\nu$, $\ell = e, \mu$), using pp collision data at $\sqrt{s} = 8$ TeV collected by the ATLAS detector at the LHC. This process has a distinct experimental signature of two same-electric-charge leptons and two jets.

Two fiducial regions are defined. The first region or "inclusive region" is defined to study the combination of electroweak and strong production mechanisms, and in this region both processes are referred to as the signal. It is defined at particle level as follows. Exactly two prompt charged leptons (τ leptons and leptons originating from τ decays are excluded) are required with the same electric charge, transverse momentum $p_T > 25$ GeV, $|\eta| < 2.5$ [12], invariant mass $m_{\ell\ell} > 20$ GeV, and angular separation $\Delta R_{\ell\ell} \equiv \sqrt{(\Delta\phi)^2 + (\Delta\eta)^2} > 0.3$. At least two jets reconstructed with the anti-k_t algorithm [13] with jet size $R = 0.4$ and with $p_T > 30$ GeV, $|\eta| < 4.5$, and separated from the leptons by $\Delta R_{\ell j} > 0.3$ are also required. The invariant mass of the two jets with the largest p_T (m_{jj}) must be larger than 500 GeV, and the magnitude of the missing transverse momentum (E_T^{miss}) calculated using all neutrinos in the final state must be greater than 40 GeV. To reduce the dependence on QED radiation, lepton momenta include contributions from photons within $\Delta R = 0.1$ of the lepton direction. The second region or "VBS region" is a subset of the inclusive region that also requires the two jets with largest p_T to be separated in rapidity [14] by $|\Delta y_{jj}| > 2.4$. This enhances the purity of electroweak $W^{\pm}W^{\pm}jj$ by removing most of the strong $W^{\pm}W^{\pm}jj$ events, which are considered as a background in this region.

* Full author list given at the end of the article.

The expected production cross sections for the $pp \to W^{\pm}W^{\pm}jj$ process in the two fiducial regions ("fiducial cross sections") are calculated using POWHEGBOX [15,16], with CT10 parton distribution functions (PDFs) [17], interfaced with PYTHIA8 [18,19] for parton showering, hadronization, and underlying event modeling. The contribution from nonresonant production of the same leptonic final state is also considered, but is strongly suppressed [16]. The cross section for the electroweak $W^{\pm}W^{\pm}jj$ process is predicted to be 1.00 ± 0.06 fb in the inclusive region and 0.88 ± 0.05 fb in the VBS region. The cross section for the strong $W^{\pm}W^{\pm}jj$ process is 0.35 ± 0.05 fb in the inclusive region and 0.098 ± 0.018 fb for the VBS region. The uncertainty on these predictions include 68% confidence level PDF uncertainties [20], parton shower, and hadronization modeling uncertainties estimated by comparing PYTHIA8 and HERWIG++ plus JIMMY [21,22], the independent variation of renormalization and factorization scales by a factor of 2, the difference between the predictions from POWHEGBOX and VBFNLO [23], and the integration error. The parton shower and generator uncertainties are dominant for electroweak production, while scale variations are dominant for strong production. Interference between electroweak and strong production is studied at leading-order accuracy using SHERPA [24] and is found to increase the combined strong and electroweak $W^{\pm}W^{\pm}jj$ cross section by $(12 \pm 6)\%$ in the inclusive region and $(7 \pm 4)\%$ in the VBS region. The total SM signal cross-section prediction in the inclusive region is 1.52 ± 0.11 fb, while the sum of electroweak and interference contributions in the VBS region is 0.95 ± 0.06 fb.

The ATLAS detector described in Ref. [25] is a multipurpose particle physics detector. It consists of an inner tracking detector (ID) surrounded by a calorimeter and a muon spectrometer (MS). Events for this analysis are selected with single-lepton (e or μ) triggers. After applying data quality requirements, the remaining data set has a total integrated luminosity of 20.3 ± 0.6 fb^{-1} [26].

Electron candidates are reconstructed from a combination of a cluster of energy deposits in the electromagnetic calorimeter and a track in the ID. They are required to have $p_T > 25$ GeV and $|\eta| < 2.47$, excluding the transition region between the barrel and endcap calorimeters ($1.37 < |\eta| < 1.52$). Candidate electrons must satisfy the tight quality definition described in Ref. [27] and reoptimized for 2012 data taking. Muon candidates are reconstructed by combining tracks in the ID and MS [28]. The combined track is required to have $p_T > 25$ GeV and $|\eta| < 2.4$. Leptons are required to originate from the same interaction vertex and, to reduce nonprompt production, calorimeter and tracker isolation requirements are applied within a cone of size $\Delta R = 0.3$.

Jets are reconstructed from clusters of energy in the calorimeter, using the anti-k_t algorithm with jet-size parameter $R = 0.4$ and calibrated using techniques from Ref. [29]. Only jets with $p_T > 30$ GeV and $|\eta| < 4.5$ are considered. Jets containing b hadrons ("b jet") with $|\eta| < 2.5$ are identified by combining information on the impact parameter significances of their tracks and explicit secondary vertex reconstruction [30]. The measurement of E_T^{miss} [31] is based on the energy collected by the electromagnetic and hadronic calorimeters, and muon tracks reconstructed by the ID and MS.

Candidate $W^{\pm}W^{\pm}jj$ events are required to have exactly two leptons (electrons or muons) with the same electric charge and at least two jets satisfying the above selection criteria. Three different final states ("channels") are considered based on the lepton flavor, namely, $e^{\pm}e^{\pm}$, $e^{\pm}\mu^{\pm}$, and $\mu^{\pm}\mu^{\pm}$. To reduce the contributions from $WZ/\gamma^* +$ jets and $ZZ +$ jets production, events are removed if they contain additional leptons reconstructed with looser isolation requirements, $p_T > 7$ GeV (6 GeV) for electrons (muons) and loose quality definition for electrons [27]. The two leptons must have $m_{\ell\ell} > 20$ GeV. The dielectron invariant mass must not be within 10 GeV of the Z boson mass to reduce $Z +$ jets background from electron charge misidentification. Events are also required to have $E_T^{\text{miss}} > 40$ GeV, and in order to reject backgrounds from nonprompt leptons, mainly $t\bar{t} \to \ell\nu jjb\bar{b}$, events must not contain a b jet. To further reduce $t\bar{t}$ and $WZ/\gamma^* +$ jets backgrounds, events in the inclusive region are required to have $m_{jj} > 500$ GeV. In addition, in the VBS region $|\Delta y_{jj}| > 2.4$ is required.

Monte Carlo (MC) simulation is used to estimate the expected signal events. The $W^{\pm}W^{\pm}jj$ processes are generated with SHERPA, using up to three jets in the matrix-element and parton shower model [24], and normalized using the expected cross section in each fiducial region (see above). Generated events are processed with the full detector simulation [32] based on GEANT4 [33], and the standard ATLAS reconstruction software.

Several SM processes enter the $W^{\pm}W^{\pm}jj$ signal regions as irreducible physics processes or through instrumental effects. About 90% of the expected prompt lepton background originates from $WZ/\gamma^* \to \ell^{\pm}\ell^{\mp}\ell^{\pm}\nu$ production that passes signal region selections when one lepton is outside of the experimental acceptance or does not satisfy the lepton identification criteria. Up to 20% of the expected WZ/γ^* contribution comes from electroweak production. Smaller contributions from $ZZ +$ jets and $t\bar{t} + W/Z$ are also considered. These "prompt lepton backgrounds" are estimated using MC simulation. In the VBS region strong $W^{\pm}W^{\pm}jj$ is estimated using simulation and normalized to the SM prediction for the fiducial cross section described above. Correction factors for lepton and jet efficiencies, additional pp interactions (pile-up), and beam-spot location are applied to the simulation to account for differences with data. Furthermore, the simulation is tuned to reproduce the calorimeter response and the muon momentum scale and resolution observed in data. Systematic uncertainties on the signal yield and backgrounds estimated from MC simulation are derived from uncertainties on the correction factors, energy smearing parameters, the E_T^{miss} modeling, and the b-tagging efficiency and mistag rate [30].

SHERPA is used to produce $WZ/\gamma^* +$ jets events, taking into account both the strong and electroweak production mechanisms. This sample is normalized to the next-to-leading-order calculation in QCD from VBFNLO in each fiducial region [34,35], with an accuracy of 14% in the inclusive region and 11% in the VBS region. The SHERPA extrapolation from the inclusive region to the VBS region differs from the VBFNLO calculation by 3%. The main sources of uncertainties on the VBFNLO normalization are from the PDF, from factorization and renormalization scale dependence, and from the parton shower model. The small tZj component in this sample is estimated using the SHERPA prediction.

The production of $ZZ +$ jets is modeled with SHERPA, while for $t\bar{t} + W/Z$ processes MADGRAPH [36] with PYTHIA8 is used. The theoretical uncertainties on the production cross sections of these processes are $\pm 19\%$ and $\pm 30\%$, respectively, dominated by the jet multiplicity modeling and the scale uncertainties.

Contributions from $W\gamma$ production, including electroweak production of $W\gamma jj$, where the photon converts to an electron-positron pair inside the detector is included in the "conversion background." It is estimated using ALPGEN [37] with HERWIG plus JIMMY and SHERPA (for electroweak $W\gamma jj$) MC samples with a total theory uncertainty of $\pm 17\%$.

The remaining conversion background originates from processes that produce oppositely charged prompt leptons where one lepton's charge is misidentified, primarily because one electron has undergone hard bremsstrahlung and subsequent photon conversion. This background is estimated from data. The dominant origins of this background are $t\bar{t} \to \ell\nu\ell\nu b\bar{b}$ and Drell-Yan lepton pair production. The electron charge misidentification rate is measured using $Z/\gamma^* \to ee$ events. The muon charge misidentification rate is found to be negligible. The background is estimated by applying the electron charge misidentification rate to data selected using all signal selection criteria except for the electric charges of the leptons, which are instead required to be opposite sign. The dominant systematic uncertainties arise from possible method bias (studied in simulation) and the statistical uncertainty in the charge misidentification rate. The total uncertainty is between 15% and 32% depending on signal region and channel.

Contributions from SM processes that produce at least one nonprompt lepton from hadron decays in jets ($W +$ jets, $t\bar{t}$, single top or multijet production, denoted by "other nonprompt background") are estimated from data events that contain one lepton passing all selections and one nonisolated or loose-quality lepton. These events, which are dominated by the nonprompt background, are scaled by a "fake rate" to predict the nonprompt background. The fake rate is the efficiency for nonprompt leptons to pass the nominal lepton selections with respect to the looser isolation and quality requirements. The fake rate for nonprompt leptons is measured in a dijet sample. The uncertainty on the nonprompt background estimate is between 39% and 52% depending on region and channel, dominated by prompt-lepton contamination in the dijet sample and the uncertainty on the extrapolation of fake rates into the signal region.

TABLE I. Expected numbers of events (exp) and measured data counts are shown by channel for each control region described in the text. The uncertainty shown is the systematic uncertainty on the expected yield.

Control region		Trilepton	≤ 1 jet	b-tagged	Low m_{jj}
$e^\pm e^\pm$	exp	36 ± 6	278 ± 28	40 ± 6	76 ± 9
	data	40	288	46	78
$e^\pm \mu^\pm$	exp	110 ± 18	288 ± 42	75 ± 13	127 ± 16
	data	104	328	82	120
$\mu^\pm \mu^\pm$	exp	60 ± 10	88 ± 14	25 ± 7	40 ± 6
	data	48	101	36	30

Contributions from double parton scattering [38] arise mainly in WZ/γ^* and dijet production. However, simulation shows they are negligible after the requirement of $m_{jj} > 500$ GeV.

Background predictions are tested in several same-electric-charge dilepton control regions summarized in Table I. The MC modeling of prompt backgrounds is tested in a trilepton control region defined by inverting the third-lepton veto and removing the $|\Delta y_{jj}|$ and m_{jj} selections. Conversion and prompt backgrounds are tested in a region with at most one jet (≤ 1 jet, in Table I). In this sample the $e^\pm e^\pm$ channel is dominated by $Z \to ee$ events, the $\mu^\pm\mu^\pm$ channel is dominated by prompt processes, and the $e^\pm\mu^\pm$ channel has a mixture of prompt, nonprompt, and conversion backgrounds. Backgrounds from nonprompt leptons originating from $t\bar{t} \to \ell\nu jjb\bar{b}$ are tested in a control region that requires at least one of the jets to be identified as a b jet. Finally, the combined background model is tested by inverting the m_{jj} selection.

The observed number of events is compared in Table II to the expected background and signal yield with systematic uncertainties for the three channels in both the inclusive and VBS signal regions. In the VBS region strong $W^\pm W^\pm jj$ is considered as background using the SM prediction and its experimental and theoretical uncertainties. The systematic uncertainty on the background prediction is about 20%, dominated by the jet reconstruction uncertainties (11%–15%) and theory uncertainties (4%–11%). An excess of events over the background expectation is observed in both signal regions and in all three channels; the combined significance over the background-only

TABLE II. Estimated background yields, observed number of data events, and predicted signal yields for the three channels are shown with their systematic uncertainty. Contributions due to interference are included in the $W^{\pm}W^{\pm}jj$ electroweak prediction.

	Inclusive region			VBS region		
	$e^{\pm}e^{\pm}$	$e^{\pm}\mu^{\pm}$	$\mu^{\pm}\mu^{\pm}$	$e^{\pm}e^{\pm}$	$e^{\pm}\mu^{\pm}$	$\mu^{\pm}\mu^{\pm}$
Prompt	3.0 ± 0.7	6.1 ± 1.3	2.6 ± 0.6	2.2 ± 0.5	4.2 ± 1.0	1.9 ± 0.5
Conversions	3.2 ± 0.7	2.4 ± 0.8	...	2.1 ± 0.5	1.9 ± 0.7	...
Other nonprompt	0.61 ± 0.30	1.9 ± 0.8	0.41 ± 0.22	0.50 ± 0.26	1.5 ± 0.6	0.34 ± 0.19
$W^{\pm}W^{\pm}jj$ Strong	0.89 ± 0.15	2.5 ± 0.4	1.42 ± 0.23	0.25 ± 0.06	0.71 ± 0.14	0.38 ± 0.08
$W^{\pm}W^{\pm}jj$ Electroweak	3.07 ± 0.30	9.0 ± 0.8	4.9 ± 0.5	2.55 ± 0.25	7.3 ± 0.6	4.0 ± 0.4
Total background	6.8 ± 1.2	10.3 ± 2.0	3.0 ± 0.6	5.0 ± 0.9	8.3 ± 1.6	2.6 ± 0.5
Total predicted	10.7 ± 1.4	21.7 ± 2.6	9.3 ± 1.0	7.6 ± 1.0	15.6 ± 2.0	6.6 ± 0.8
Data	12	26	12	6	18	10

hypothesis is 4.5 standard deviations in the inclusive region and 3.6 standard deviations in the VBS region. The expected significance for a SM $W^{\pm}W^{\pm}jj$ signal is 3.4 standard deviations in the inclusive region and 2.8 in the VBS region.

Figure 1 shows the expected and observed m_{jj} distribution after all inclusive region selection criteria are applied, except $m_{jj} > 500$ GeV. Figure 2 shows the $|\Delta y_{jj}|$ distribution after the inclusive region selections. All three dilepton channels are summed in both figures. The observed excess is consistent with the expected event topology for $W^{\pm}W^{\pm}jj$ production.

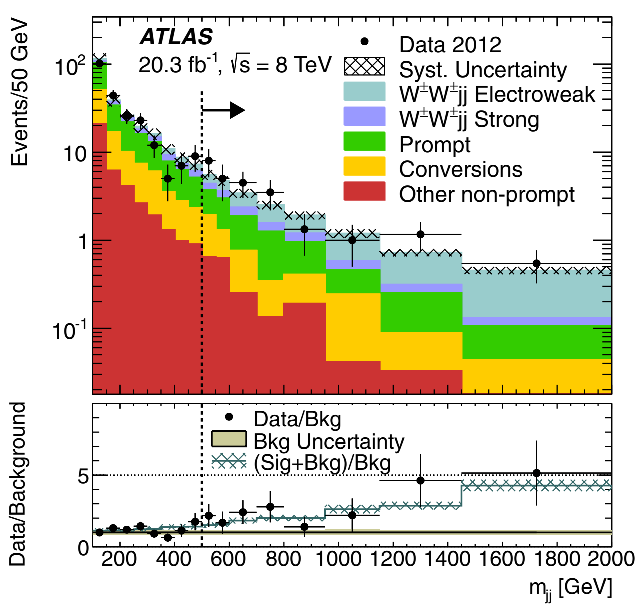

FIG. 1 (color online). The m_{jj} distribution for events passing the inclusive region selections except for the m_{jj} selection indicated by the dashed line. The black hatched band in the upper plot represents the systematic uncertainty on the total prediction. On the lower plot the shaded band represents the fractional uncertainty of the total background while the solid line and hatched band represents the ratio of the total prediction to background only and its uncertainty. The $W^{\pm}W^{\pm}jj$ prediction is normalized to the SM expectation.

We interpret the excess over background as $W^{\pm}W^{\pm}jj$ production, and the fiducial cross sections in the two regions (σ^{fid}) are measured by combining the three decay channels in a likelihood function. Systematic uncertainties are taken into account with nuisance parameters.

The signal efficiency in each fiducial region is defined as the number of expected signal events after selections divided by the number of events passing the respective fiducial region selections at the particle level. The efficiency accounts for the detector reconstruction, migration into and out of the fiducial volume, identification, and trigger efficiency; it is 56%, 72%, 77% for the inclusive region and 57%, 73%, 83% for the VBS region in the $e^{\pm}e^{\pm}$, $e^{\pm}\mu^{\pm}$, and $\mu^{\pm}\mu^{\pm}$ channels, respectively. The efficiency also accounts for the contribution of leptonic τ decays, which are not included in the fiducial cross-section definition: 10% of signal candidates are expected to originate from leptonic τ decays. The uncertainty on the signal efficiency is dominated by the jet reconstruction uncertainty of 6%.

The measured fiducial cross section for strong and electroweak $W^{\pm}W^{\pm}jj$ production in the inclusive region

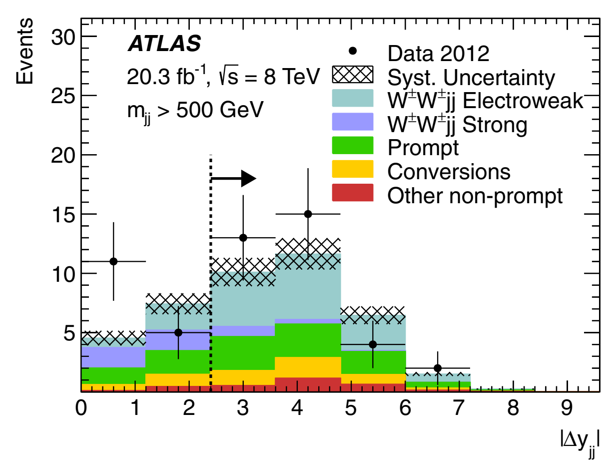

FIG. 2 (color online). The $|\Delta y_{jj}|$ distribution for events passing all inclusive region selections. The $|\Delta y_{jj}|$ selection is indicated by a dashed line. The $W^{\pm}W^{\pm}jj$ prediction is normalized to the SM expectation.

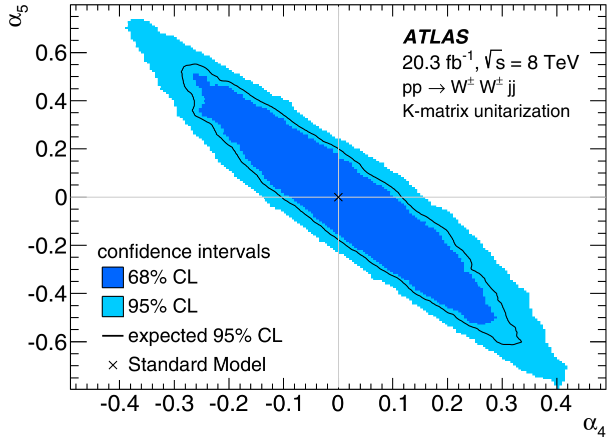

FIG. 3 (color online). Limits on (α_4,α_5). Points outside of the solid light ellipse are excluded by the data at 95% confidence level (C.L.). Points outside the inner dark ellipse are excluded at the 68% confidence level. The expected exclusion is given by the solid line.

is $\sigma^{\rm fid} = 2.1 \pm 0.5({\rm stat}) \pm 0.3({\rm syst})$ fb. The measured fiducial cross section for electroweak $W^{\pm}W^{\pm}jj$ production, including interference with strong production in the VBS region, is $\sigma^{\rm fid} = 1.3 \pm 0.4({\rm stat}) \pm 0.2({\rm syst})$ fb. The measured cross sections are in agreement with the respective SM expectations of 1.52 ± 0.11 fb and 0.95 ± 0.06 fb.

Additional contributions to $W^{\pm}W^{\pm}jj$ production can be expressed in a model-independent way using higher-dimensional operators leading to anomalous quartic gauge boson couplings (AQGCs). The measured cross section in the VBS fiducial region is used to set limits on AQGCs affecting vertices with four interacting W bosons. The WHIZARD event generator [39] is used to generate $W^{\pm}W^{\pm}jj$ events with AQGCs using a K-matrix unitarization method [40]. Following existing notations [40,41], deviations from the SM (which includes a SM Higgs with $m_H = 126$ GeV) are parametrized in terms of two parameters (α_4, α_5). The reconstruction efficiency is derived using simulated WHIZARD samples combined with PYTHIA8. The difference with respect to SHERPA for the SM case is taken as additional systematic uncertainty. The reconstruction efficiency increases with increasing $\alpha_{4,5}$ values, but the effect is small compared to the increase in the fiducial cross sections in the same parameter space. The expected and observed 95% confidence intervals derived from the profile likelihood function are shown in Fig. 3. The one-dimensional projection at $\alpha_{5,4} = 0$ is, respectively, $-0.14 < \alpha_4 < 0.16$ and $-0.23 < \alpha_5 < 0.24$, compared to an expected $-0.10 < \alpha_4 < 0.12$ and $-0.18 < \alpha_5 < 0.20$.

In conclusion, a significant excess of events over background predictions is found using 20.3 fb^{-1} of pp collision data at $\sqrt{s} = 8$ TeV recorded by the ATLAS detector at the LHC. This excess is consistent with SM $W^{\pm}W^{\pm}jj$ production. Two fiducial cross sections are measured in regions with different sensitivities to the electroweak and strong $W^{\pm}W^{\pm}jj$ processes. The measured cross sections are in good agreement with SM predictions. In addition, the first limits on the $\alpha_{4,5}$ AQGC parameters are set.

We thank CERN for the very successful operation of the LHC, as well as the support staff from our institutions without whom ATLAS could not be operated efficiently. We acknowledge the support of ANPCyT, Argentina; YerPhI, Armenia; ARC, Australia; BMWF and FWF, Austria; ANAS, Azerbaijan; SSTC, Belarus; CNPq and FAPESP, Brazil; NSERC, NRC and CFI, Canada; CERN; CONICYT, Chile; CAS, MOST, and NSFC, China; COLCIENCIAS, Colombia; MSMT CR, MPO CR, and VSC CR, Czech Republic; DNRF, DNSRC, and Lundbeck Foundation, Denmark; EPLANET and ERC, European Union; IN2P3-CNRS, CEA-DSM/IRFU, France; GNSF, Georgia; BMBF, DFG, HGF, MPG, and AvH Foundation, Germany; GSRT, Greece; ISF, MINERVA, GIF, DIP, and Benoziyo Center, Israel; INFN, Italy; MEXT and JSPS, Japan; CNRST, Morocco; FOM and NWO, Netherlands; BRF and RCN, Norway; MNiSW, Poland; GRICES and FCT, Portugal; MERYS (MECTS), Romania; MES of Russia and ROSATOM, Russian Federation; JINR; MSTD, Serbia; MSSR, Slovakia; ARRS and MVZT, Slovenia; DST/NRF, South Africa; MICINN, Spain; SRC and Wallenberg Foundation, Sweden; SER, SNSF, and Cantons of Bern and Geneva, Switzerland; NSC, Taiwan; TAEK, Turkey; STFC, the Royal Society, and Leverhulme Trust, United Kingdom; DOE and NSF, United States of America. The crucial computing support from all WLCG partners is acknowledged gratefully, in particular from CERN and the ATLAS Tier-1 facilities at TRIUMF (Canada), NDGF (Denmark, Norway, Sweden), CC-IN2P3 (France), KIT/GridKA (Germany), INFN-CNAF (Italy), NL-T1 (Netherlands), PIC (Spain), ASGC (Taiwan), RAL (UK) and BNL (USA) and in the Tier-2 facilities worldwide.

[1] J. Bagger, V. Barger, K. Cheung, J. Gunion, T. Han, G. A. Ladinsky, R. Rosenfeld, and C.-P. Yuan, Phys. Rev. D **49**, 1246 (1994).
[2] J. Bagger, V. Barger, K. Cheung, J. Gunion, T. Han, G. A. Ladinsky, R. Rosenfeld, and C.-P. Yuan, Phys. Rev. D **52**, 3878 (1995).
[3] M. J. G. Veltman, Acta Phys. Pol. B **8**, 475 (1977).
[4] B. W. Lee, C. Quigg, and H. B. Thacker, Phys. Rev. Lett. **38**, 883 (1977).
[5] B. W. Lee, C. Quigg, and H. B. Thacker, Phys. Rev. D **16**, 1519 (1977).
[6] ATLAS Collaboration, Phys. Lett. B **716**, 1 (2012).
[7] CMS Collaboration, Phys. Lett. B **716**, 30 (2012).
[8] D. Espriu and B. Yencho, Phys. Rev. D **87**, 055017 (2013).
[9] J. Chang, K. Cheung, C. T. Lu, and T.-C. Yuan, Phys. Rev. D **87**, 093005 (2013).

[10] R. N. Cahn, S. D. Ellis, R. Kleiss, and W. J. Stirling, Phys. Rev. D **35**, 1626 (1987).
[11] E. Accomando, A. Ballestrero, A. Belhouari, and E. Maina, Phys. Rev. D **74**, 073010 (2006).
[12] ATLAS uses a right-handed coordinate system with its origin at the nominal interaction point (IP) in the center of the detector and the z axis along the beam pipe. The x axis points from the IP to the center of the LHC ring, and the y axis points upward. Cylindrical coordinates (r, ϕ) are used in the transverse plane, ϕ being the azimuthal angle around the beam pipe. The pseudorapidity is defined in terms of the polar angle θ as $\eta = -\ln\tan(\theta/2)$. Transverse projections are defined relative to the beam axis.
[13] M. Cacciari, G. P. Salam, and G. Soyez, J. High Energy Phys. 04 (2008) 063.
[14] Rapidity is defined as $y = (1/2)\ln[(E + p_z)/(E - p_z)]$.
[15] P. Nason, J. High Energy Phys. 11 (2004) 040; S. Frixione, P. Nason, and C. Oleari, J. High Energy Phys. 11 (2007) 070; S. Alioli, P. Nason, C. Oleari, and E. Re, J. High Energy Phys. 06 (2010) 043.
[16] B. Jäger, C. Oleari, and D. Zeppenfeld, Phys. Rev. D **80**, 034022 (2009); B. Jäger and G. Zanderighi, J. High Energy Phys. 11 (2011) 055; T. Melia, K. Melnikov, R. Rontsch, and G. Zanderighi, J. High Energy Phys. 12 (2010) 053; T. Melia, P. Nason, R. Rontsch, and G. Zanderighi, Eur. Phys. J. C **71**, 1670 (2011).
[17] H.-L. Lai, M. Guzzi, J. Huston, Z. Li, P. M. Nadolsky, J. Pumplin, and C.-P. Yuan, Phys. Rev. D **82**, 074024 (2010).
[18] T. Sjöstrand, S. Mrenna, and P. Skands, J. High Energy Phys. 05 (2006) 026; T. Sjöstrand, S. Mrenna, and P. Skands, Comput. Phys. Commun. **178**, 852 (2008).
[19] ATLAS Collaboration, Report No. ATL-PHYS-PUB-2012-003, 2012, https://cds.cern.ch/record/1474107.
[20] J. M. Campbell, J. W. Huston, and W. J. Stirling, Rep. Prog. Phys. **70**, 89 (2007).
[21] G. Corcella, I. G. Knowles, G. Marchesini, S. Moretti, K. Odagiri, P. Richardson, M. H. Seymour, and B. R. Webber, J. High Energy Phys. 01 (2001) 010.
[22] J. M. Butterworth, J. R. Forshaw, and M. H. Seymour, Z. Phys. C **72**, 637 (1996).
[23] K. Arnold *et al.*, Comput. Phys. Commun. **180**, 1661 (2009); J. Baglio *et al.*, arXiv:1107.4038; K. Arnold *et al.*, arXiv:1207.4975; B. Jäger, C. Oleari, and D. Zeppenfeld, Phys. Rev. D **80**, 034022 (2009).
[24] T. Gleisberg, S. Hoeche, F. Krauss, M. Schoenherr, S. Schumann, F. Siegert, and J. Winter, J. High Energy Phys. 02 (2009) 007; T. Gleisberg and S. Hoeche, J. High Energy Phys. 12 (2008) 039; S. Schumann and F. Krauss, J. High Energy Phys. 03 (2008) 038; S. Hoeche, F. Krauss, S. Schumann, and F. Siegert, J. High Energy Phys. 05 (2009) 053.
[25] ATLAS Collaboration, JINST **3**, S08003 (2008).
[26] ATLAS Collaboration, Eur. Phys. J. C **73**, 2518 (2013).
[27] ATLAS Collaboration, arXiv:1404.2240; ATLAS Collaboration, Eur. Phys. J. C **72**, 1909 (2012).
[28] ATLAS Collaboration, Phys. Lett. B **707**, 438 (2012).
[29] ATLAS Collaboration, Eur. Phys. J. C **73**, 2304 (2013).
[30] ATLAS Collaboration, Report No. ATLAS-CONF-2011-102, 2011, http://cdsweb.cern.ch/record/1369219.
[31] ATLAS Collaboration, Eur. Phys. J. C **72**, 1844 (2012).
[32] ATLAS Collaboration, Eur. Phys. J. C **70**, 823 (2010).
[33] S. Agostinelli *et al.*, Nucl. Instrum. Methods Phys. Res., Sect. A **506**, 250 (2003).
[34] G. Bozzi, B. Jäger, C. Oleari, and D. Zeppenfeld, Phys. Rev. D **75**, 073004 (2007).
[35] F. Campanario, M. Kerner, L. D. Ninh, and D. Zeppenfeld, Phys. Rev. Lett. **111**, 052003 (2013).
[36] J. Alwall, P. Demin, S. Visscher, R. Frederix, M. Herquet, F. Maltoni, T. Plehn, D. L. Rainwater, and T. Stelzer, J. High Energy Phys. 09 (2007) 028.
[37] M. L. Mangano, M. Moretti, F. Piccinini, R. Pittau, and A. Polosa, J. High Energy Phys. 07 (2003) 001.
[38] A. Del Fabbro and D. Treleani, Phys. Rev. D **63**, 057901 (2001).
[39] W. Kilian, T. Ohl, and J. Reuter, Eur. Phys. J. C **71**, 1742 (2011); M. Moretti, T. Ohl, and J. Reuter, arXiv:hep-ph/0102195.
[40] A. Alboteanu, W. Kilian, and J. Reuter, J. High Energy Phys. 11 (2008) 010.
[41] T. Appelquist and C. Bernard, Phys. Rev. D **22**, 200 (1980); A. C. Longhitano, Phys. Rev. D **22**, 1166 (1980); Nucl. Phys. **B188**, 118 (1981).

G. Aad,[84] B. Abbott,[112] J. Abdallah,[152] S. Abdel Khalek,[116] O. Abdinov,[11] R. Aben,[106] B. Abi,[113] M. Abolins,[89] O. S. AbouZeid,[159] H. Abramowicz,[154] H. Abreu,[153] R. Abreu,[30] Y. Abulaiti,[147a,147b] B. S. Acharya,[165a,165b,b] L. Adamczyk,[38a] D. L. Adams,[25] J. Adelman,[177] S. Adomeit,[99] T. Adye,[130] T. Agatonovic-Jovin,[13a] J. A. Aguilar-Saavedra,[125a,125f] M. Agustoni,[17] S. P. Ahlen,[22] F. Ahmadov,[64,c] G. Aielli,[134a,134b] H. Akerstedt,[147a,147b] T. P. A. Åkesson,[80] G. Akimoto,[156] A. V. Akimov,[95] G. L. Alberghi,[20a,20b] J. Albert,[170] S. Albrand,[55] M. J. Alconada Verzini,[70] M. Aleksa,[30] I. N. Aleksandrov,[64] C. Alexa,[26a] G. Alexander,[154] G. Alexandre,[49] T. Alexopoulos,[10] M. Alhroob,[165a,165c] G. Alimonti,[90a] L. Alio,[84] J. Alison,[31] B. M. M. Allbrooke,[18] L. J. Allison,[71] P. P. Allport,[73] J. Almond,[83] A. Aloisio,[103a,103b] A. Alonso,[36] F. Alonso,[70] C. Alpigiani,[75] A. Altheimer,[35] B. Alvarez Gonzalez,[89] M. G. Alviggi,[103a,103b] K. Amako,[65] Y. Amaral Coutinho,[24a] C. Amelung,[23] D. Amidei,[88] S. P. Amor Dos Santos,[125a,125c] A. Amorim,[125a,125b] S. Amoroso,[48] N. Amram,[154] G. Amundsen,[23] C. Anastopoulos,[140] L. S. Ancu,[49] N. Andari,[30] T. Andeen,[35] C. F. Anders,[58b] G. Anders,[30] K. J. Anderson,[31] A. Andreazza,[90a,90b] V. Andrei,[58a] X. S. Anduaga,[70] S. Angelidakis,[9] I. Angelozzi,[106] P. Anger,[44] A. Angerami,[35] F. Anghinolfi,[30] A. V. Anisenkov,[108] N. Anjos,[125a] A. Annovi,[47] A. Antonaki,[9] M. Antonelli,[47]

A. Antonov,[97] J. Antos,[145b] F. Anulli,[133a] M. Aoki,[65] L. Aperio Bella,[18] R. Apolle,[119,d] G. Arabidze,[89] I. Aracena,[144] Y. Arai,[65] J. P. Araque,[125a] A. T. H. Arce,[45] J-F. Arguin,[94] S. Argyropoulos,[42] M. Arik,[19a] A. J. Armbruster,[30] O. Arnaez,[30] V. Arnal,[81] H. Arnold,[48] M. Arratia,[28] O. Arslan,[21] A. Artamonov,[96] G. Artoni,[23] S. Asai,[156] N. Asbah,[42] A. Ashkenazi,[154] B. Åsman,[147a,147b] L. Asquith,[6] K. Assamagan,[25] R. Astalos,[145a] M. Atkinson,[166] N. B. Atlay,[142] B. Auerbach,[6] K. Augsten,[127] M. Aurousseau,[146b] G. Avolio,[30] G. Azuelos,[94,e] Y. Azuma,[156] M. A. Baak,[30] C. Bacci,[135a,135b] H. Bachacou,[137] K. Bachas,[155] M. Backes,[30] M. Backhaus,[30] J. Backus Mayes,[144] E. Badescu,[26a] P. Bagiacchi,[133a,133b] P. Bagnaia,[133a,133b] Y. Bai,[33a] T. Bain,[35] J. T. Baines,[130] O. K. Baker,[177] S. Baker,[77] P. Balek,[128] F. Balli,[137] E. Banas,[39] Sw. Banerjee,[174] A. A. E. Bannoura,[176] V. Bansal,[170] H. S. Bansil,[18] L. Barak,[173] S. P. Baranov,[95] E. L. Barberio,[87] D. Barberis,[50a,50b] M. Barbero,[84] T. Barillari,[100] M. Barisonzi,[176] T. Barklow,[144] N. Barlow,[28] B. M. Barnett,[130] R. M. Barnett,[15] Z. Barnovska,[5] A. Baroncelli,[135a] G. Barone,[49] A. J. Barr,[119] F. Barreiro,[81] J. Barreiro Guimarães da Costa,[57] R. Bartoldus,[144] A. E. Barton,[71] P. Bartos,[145a] V. Bartsch,[150] A. Bassalat,[116] A. Basye,[166] R. L. Bates,[53] L. Batkova,[145a] J. R. Batley,[28] M. Battaglia,[138] M. Battistin,[30] F. Bauer,[137] H. S. Bawa,[144,f] T. Beau,[79] P. H. Beauchemin,[162] R. Beccherle,[123a,123b] P. Bechtle,[21] H. P. Beck,[17] K. Becker,[176] S. Becker,[99] M. Beckingham,[139] C. Becot,[116] A. J. Beddall,[19c] A. Beddall,[19c] S. Bedikian,[177] V. A. Bednyakov,[64] C. P. Bee,[149] L. J. Beemster,[106] T. A. Beermann,[176] M. Begel,[25] K. Behr,[119] C. Belanger-Champagne,[86] P. J. Bell,[49] W. H. Bell,[49] G. Bella,[154] L. Bellagamba,[20a] A. Bellerive,[29] M. Bellomo,[85] K. Belotskiy,[97] O. Beltramello,[30] O. Benary,[154] D. Benchekroun,[136a] K. Bendtz,[147a,147b] N. Benekos,[166] Y. Benhammou,[154] E. Benhar Noccioli,[49] J. A. Benitez Garcia,[160b] D. P. Benjamin,[45] J. R. Bensinger,[23] K. Benslama,[131] S. Bentvelsen,[106] D. Berge,[106] E. Bergeaas Kuutmann,[16] N. Berger,[5] F. Berghaus,[170] E. Berglund,[106] J. Beringer,[15] C. Bernard,[22] P. Bernat,[77] C. Bernius,[78] F. U. Bernlochner,[170] T. Berry,[76] P. Berta,[128] C. Bertella,[84] G. Bertoli,[147a,147b] F. Bertolucci,[123a,123b] D. Bertsche,[112] M. I. Besana,[90a] G. J. Besjes,[105] O. Bessidskaia,[147a,147b] M. F. Bessner,[42] N. Besson,[137] C. Betancourt,[48] S. Bethke,[100] W. Bhimji,[46] R. M. Bianchi,[124] L. Bianchini,[23] M. Bianco,[30] O. Biebel,[99] S. P. Bieniek,[77] K. Bierwagen,[54] J. Biesiada,[15] M. Biglietti,[135a] J. Bilbao De Mendizabal,[49] H. Bilokon,[47] M. Bindi,[54] S. Binet,[116] A. Bingul,[19c] C. Bini,[133a,133b] C. W. Black,[151] J. E. Black,[144] K. M. Black,[22] D. Blackburn,[139] R. E. Blair,[6] J.-B. Blanchard,[137] T. Blazek,[145a] I. Bloch,[42] C. Blocker,[23] W. Blum,[82,a] U. Blumenschein,[54] G. J. Bobbink,[106] V. S. Bobrovnikov,[108] S. S. Bocchetta,[80] A. Bocci,[45] C. Bock,[99] C. R. Boddy,[119] M. Boehler,[48] J. Boek,[176] T. T. Boek,[176] J. A. Bogaerts,[30] A. G. Bogdanchikov,[108] A. Bogouch,[91,a] C. Bohm,[147a] J. Bohm,[126] V. Boisvert,[76] T. Bold,[38a] V. Boldea,[26a] A. S. Boldyrev,[98] M. Bomben,[79] M. Bona,[75] M. Boonekamp,[137] A. Borisov,[129] G. Borissov,[71] M. Borri,[83] S. Borroni,[42] J. Bortfeldt,[99] V. Bortolotto,[135a,135b] K. Bos,[106] D. Boscherini,[20a] M. Bosman,[12] H. Boterenbrood,[106] J. Boudreau,[124] J. Bouffard,[2] E. V. Bouhova-Thacker,[71] D. Boumediene,[34] C. Bourdarios,[116] N. Bousson,[113] S. Boutouil,[136d] A. Boveia,[31] J. Boyd,[30] I. R. Boyko,[64] I. Bozovic-Jelisavcic,[13b] J. Bracinik,[18] A. Brandt,[8] G. Brandt,[15] O. Brandt,[58a] U. Bratzler,[157] B. Brau,[85] J. E. Brau,[115] H. M. Braun,[176,a] S. F. Brazzale,[165a,165c] B. Brelier,[159] K. Brendlinger,[121] A. J. Brennan,[87] R. Brenner,[167] S. Bressler,[173] K. Bristow,[146c] T. M. Bristow,[46] D. Britton,[53] F. M. Brochu,[28] I. Brock,[21] R. Brock,[89] C. Bromberg,[89] J. Bronner,[100] G. Brooijmans,[35] T. Brooks,[76] W. K. Brooks,[32b] J. Brosamer,[15] E. Brost,[115] G. Brown,[83] J. Brown,[55] P. A. Bruckman de Renstrom,[39] D. Bruncko,[145b] R. Bruneliere,[48] S. Brunet,[60] A. Bruni,[20a] G. Bruni,[20a] M. Bruschi,[20a] L. Bryngemark,[80] T. Buanes,[14] Q. Buat,[143] F. Bucci,[49] P. Buchholz,[142] R. M. Buckingham,[119] A. G. Buckley,[53] S. I. Buda,[26a] I. A. Budagov,[64] F. Buehrer,[48] L. Bugge,[118] M. K. Bugge,[118] O. Bulekov,[97] A. C. Bundock,[73] H. Burckhart,[30] S. Burdin,[73] B. Burghgrave,[107] S. Burke,[130] I. Burmeister,[43] E. Busato,[34] D. Büscher,[48] V. Büscher,[82] P. Bussey,[53] C. P. Buszello,[167] B. Butler,[57] J. M. Butler,[22] A. I. Butt,[3] C. M. Buttar,[53] J. M. Butterworth,[77] P. Butti,[106] W. Buttinger,[28] A. Buzatu,[53] M. Byszewski,[10] S. Cabrera Urbán,[168] D. Caforio,[20a,20b] O. Cakir,[4a] P. Calafiura,[15] A. Calandri,[137] G. Calderini,[79] P. Calfayan,[99] R. Calkins,[107] L. P. Caloba,[24a] D. Calvet,[34] S. Calvet,[34] R. Camacho Toro,[49] S. Camarda,[42] D. Cameron,[118] L. M. Caminada,[15] R. Caminal Armadans,[12] S. Campana,[30] M. Campanelli,[77] A. Campoverde,[149] V. Canale,[103a,103b] A. Canepa,[160a] M. Cano Bret,[75] J. Cantero,[81] R. Cantrill,[76] T. Cao,[40] M. D. M. Capeans Garrido,[30] I. Caprini,[26a] M. Caprini,[26a] M. Capua,[37a,37b] R. Caputo,[82] R. Cardarelli,[134a] T. Carli,[30] G. Carlino,[103a] L. Carminati,[90a,90b] S. Caron,[105] E. Carquin,[32a] G. D. Carrillo-Montoya,[146c] J. R. Carter,[28] J. Carvalho,[125a,125c] D. Casadei,[77] M. P. Casado,[12] M. Casolino,[12] E. Castaneda-Miranda,[146b] A. Castelli,[106] V. Castillo Gimenez,[168] N. F. Castro,[125a] P. Catastini,[57] A. Catinaccio,[30] J. R. Catmore,[118] A. Cattai,[30] G. Cattani,[134a,134b] S. Caughron,[89] V. Cavaliere,[166] D. Cavalli,[90a] M. Cavalli-Sforza,[12] V. Cavasinni,[123a,123b] F. Ceradini,[135a,135b] B. Cerio,[45] K. Cerny,[128] A. S. Cerqueira,[24b] A. Cerri,[150] L. Cerrito,[75] F. Cerutti,[15] M. Cerv,[30] A. Cervelli,[17] S. A. Cetin,[19b] A. Chafaq,[136a] D. Chakraborty,[107] I. Chalupkova,[128] K. Chan,[3] P. Chang,[166] B. Chapleau,[86] J. D. Chapman,[28] D. Charfeddine,[116] D. G. Charlton,[18] C. C. Chau,[159] C. A. Chavez Barajas,[150]

S. Cheatham,[86] A. Chegwidden,[89] S. Chekanov,[6] S. V. Chekulaev,[160a] G. A. Chelkov,[64] M. A. Chelstowska,[88] C. Chen,[63] H. Chen,[25] K. Chen,[149] L. Chen,[33d,g] S. Chen,[33c] X. Chen,[146c] Y. Chen,[35] H. C. Cheng,[88] Y. Cheng,[31] A. Cheplakov,[64] R. Cherkaoui El Moursli,[136e] V. Chernyatin,[25,a] E. Cheu,[7] L. Chevalier,[137] V. Chiarella,[47] G. Chiefari,[103a,103b] J. T. Childers,[6] A. Chilingarov,[71] G. Chiodini,[72a] A. S. Chisholm,[18] R. T. Chislett,[77] A. Chitan,[26a] M. V. Chizhov,[64] S. Chouridou,[9] B. K. B. Chow,[99] D. Chromek-Burckhart,[30] M. L. Chu,[152] J. Chudoba,[126] J. J. Chwastowski,[39] L. Chytka,[114] G. Ciapetti,[133a,133b] A. K. Ciftci,[4a] R. Ciftci,[4a] D. Cinca,[62] V. Cindro,[74] A. Ciocio,[15] P. Cirkovic,[13b] Z. H. Citron,[173] M. Citterio,[90a] M. Ciubancan,[26a] A. Clark,[49] P. J. Clark,[46] R. N. Clarke,[15] W. Cleland,[124] J. C. Clemens,[84] C. Clement,[147a,147b] Y. Coadou,[84] M. Cobal,[165a,165c] A. Coccaro,[139] J. Cochran,[63] L. Coffey,[23] J. G. Cogan,[144] J. Coggeshall,[166] B. Cole,[35] S. Cole,[107] A. P. Colijn,[106] J. Collot,[55] T. Colombo,[58c] G. Colon,[85] G. Compostella,[100] P. Conde Muiño,[125a,125b] E. Coniavitis,[167] M. C. Conidi,[12] S. H. Connell,[146b] I. A. Connelly,[76] S. M. Consonni,[90a,90b] V. Consorti,[48] S. Constantinescu,[26a] C. Conta,[120a,120b] G. Conti,[57] F. Conventi,[103a,h] M. Cooke,[15] B. D. Cooper,[77] A. M. Cooper-Sarkar,[119] N. J. Cooper-Smith,[76] K. Copic,[15] T. Cornelissen,[176] M. Corradi,[20a] F. Corriveau,[86,i] A. Corso-Radu,[164] A. Cortes-Gonzalez,[12] G. Cortiana,[100] G. Costa,[90a] M. J. Costa,[168] D. Costanzo,[140] D. Côté,[8] G. Cottin,[28] G. Cowan,[76] B. E. Cox,[83] K. Cranmer,[109] G. Cree,[29] S. Crépé-Renaudin,[55] F. Crescioli,[79] W. A. Cribbs,[147a,147b] M. Crispin Ortuzar,[119] M. Cristinziani,[21] V. Croft,[105] G. Crosetti,[37a,37b] C.-M. Cuciuc,[26a] T. Cuhadar Donszelmann,[140] J. Cummings,[177] M. Curatolo,[47] C. Cuthbert,[151] H. Czirr,[142] P. Czodrowski,[3] Z. Czyczula,[177] S. D'Auria,[53] M. D'Onofrio,[73] M. J. Da Cunha Sargedas De Sousa,[125a,125b] C. Da Via,[83] W. Dabrowski,[38a] A. Dafinca,[119] T. Dai,[88] O. Dale,[14] F. Dallaire,[94] C. Dallapiccola,[85] M. Dam,[36] A. C. Daniells,[18] M. Dano Hoffmann,[137] V. Dao,[105] G. Darbo,[50a] S. Darmora,[8] J. A. Dassoulas,[42] A. Dattagupta,[60] W. Davey,[21] C. David,[170] T. Davidek,[128] E. Davies,[119,d] M. Davies,[154] O. Davignon,[79] A. R. Davison,[77] P. Davison,[77] Y. Davygora,[58a] E. Dawe,[143] I. Dawson,[140] R. K. Daya-Ishmukhametova,[85] K. De,[8] R. de Asmundis,[103a] S. De Castro,[20a,20b] S. De Cecco,[79] N. De Groot,[105] P. de Jong,[106] H. De la Torre,[81] F. De Lorenzi,[63] L. De Nooij,[106] D. De Pedis,[133a] A. De Salvo,[133a] U. De Sanctis,[165a,165b] A. De Santo,[150] J. B. De Vivie De Regie,[116] W. J. Dearnaley,[71] R. Debbe,[25] C. Debenedetti,[46] B. Dechenaux,[55] D. V. Dedovich,[64] I. Deigaard,[106] J. Del Peso,[81] T. Del Prete,[123a,123b] F. Deliot,[137] C. M. Delitzsch,[49] M. Deliyergiyev,[74] A. Dell'Acqua,[30] L. Dell'Asta,[22] M. Dell'Orso,[123a,123b] M. Della Pietra,[103a,h] D. della Volpe,[49] M. Delmastro,[5] P. A. Delsart,[55] C. Deluca,[106] S. Demers,[177] M. Demichev,[64] A. Demilly,[79] S. P. Denisov,[129] D. Derendarz,[39] J. E. Derkaoui,[136d] F. Derue,[79] P. Dervan,[73] K. Desch,[21] C. Deterre,[42] P. O. Deviveiros,[106] A. Dewhurst,[130] S. Dhaliwal,[106] A. Di Ciaccio,[134a,134b] L. Di Ciaccio,[5] A. Di Domenico,[133a,133b] C. Di Donato,[103a,103b] A. Di Girolamo,[30] B. Di Girolamo,[30] A. Di Mattia,[153] B. Di Micco,[135a,135b] R. Di Nardo,[47] A. Di Simone,[48] R. Di Sipio,[20a,20b] D. Di Valentino,[29] M. A. Diaz,[32a] E. B. Diehl,[88] J. Dietrich,[42] T. A. Dietzsch,[58a] S. Diglio,[84] A. Dimitrievska,[13a] J. Dingfelder,[21] C. Dionisi,[133a,133b] P. Dita,[26a] S. Dita,[26a] F. Dittus,[30] F. Djama,[84] T. Djobava,[51b] M. A. B. do Vale,[24c] A. Do Valle Wemans,[125a,125g] T. K. O. Doan,[5] D. Dobos,[30] C. Doglioni,[49] T. Doherty,[53] T. Dohmae,[156] J. Dolejsi,[128] Z. Dolezal,[128] B. A. Dolgoshein,[97,a] M. Donadelli,[24d] S. Donati,[123a,123b] P. Dondero,[120a,120b] J. Donini,[34] J. Dopke,[30] A. Doria,[103a] M. T. Dova,[70] A. T. Doyle,[53] M. Dris,[10] J. Dubbert,[88] S. Dube,[15] E. Dubreuil,[34] E. Duchovni,[173] G. Duckeck,[99] O. A. Ducu,[26a] D. Duda,[176] A. Dudarev,[30] F. Dudziak,[63] L. Duflot,[116] L. Duguid,[76] M. Dührssen,[30] M. Dunford,[58a] H. Duran Yildiz,[4a] M. Düren,[52] A. Durglishvili,[51b] M. Dwuznik,[38a] M. Dyndal,[38a] J. Ebke,[99] W. Edson,[2] N. C. Edwards,[46] W. Ehrenfeld,[21] T. Eifert,[144] G. Eigen,[14] K. Einsweiler,[15] T. Ekelof,[167] M. El Kacimi,[136c] M. Ellert,[167] S. Elles,[5] F. Ellinghaus,[82] N. Ellis,[30] J. Elmsheuser,[99] M. Elsing,[30] D. Emeliyanov,[130] Y. Enari,[156] O. C. Endner,[82] M. Endo,[117] R. Engelmann,[149] J. Erdmann,[177] A. Ereditato,[17] D. Eriksson,[147a] G. Ernis,[176] J. Ernst,[2] M. Ernst,[25] J. Ernwein,[137] D. Errede,[166] S. Errede,[166] E. Ertel,[82] M. Escalier,[116] H. Esch,[43] C. Escobar,[124] B. Esposito,[47] A. I. Etienvre,[137] E. Etzion,[154] H. Evans,[60] A. Ezhilov,[122] L. Fabbri,[20a,20b] G. Facini,[31] R. M. Fakhrutdinov,[129] S. Falciano,[133a] R. J. Falla,[77] J. Faltova,[128] Y. Fang,[33a] M. Fanti,[90a,90b] A. Farbin,[8] A. Farilla,[135a] T. Farooque,[12] S. Farrell,[164] S. M. Farrington,[171] P. Farthouat,[30] F. Fassi,[168] P. Fassnacht,[30] D. Fassouliotis,[9] A. Favareto,[50a,50b] L. Fayard,[116] P. Federic,[145a] O. L. Fedin,[122,j] W. Fedorko,[169] M. Fehling-Kaschek,[48] S. Feigl,[30] L. Feligioni,[84] C. Feng,[33d] E. J. Feng,[6] H. Feng,[88] A. B. Fenyuk,[129] S. Fernandez Perez,[30] S. Ferrag,[53] J. Ferrando,[53] A. Ferrari,[167] P. Ferrari,[106] R. Ferrari,[120a] D. E. Ferreira de Lima,[53] A. Ferrer,[168] D. Ferrere,[49] C. Ferretti,[88] A. Ferretto Parodi,[50a,50b] M. Fiascaris,[31] F. Fiedler,[82] A. Filipčič,[74] M. Filipuzzi,[42] F. Filthaut,[105] M. Fincke-Keeler,[170] K. D. Finelli,[151] M. C. N. Fiolhais,[125a,125c] L. Fiorini,[168] A. Firan,[40] J. Fischer,[176] W. C. Fisher,[89] E. A. Fitzgerald,[23] M. Flechl,[48] I. Fleck,[142] P. Fleischmann,[88] S. Fleischmann,[176] G. T. Fletcher,[140] G. Fletcher,[75] T. Flick,[176] A. Floderus,[80] L. R. Flores Castillo,[174,k] A. C. Florez Bustos,[160b] M. J. Flowerdew,[100] A. Formica,[137] A. Forti,[83] D. Fortin,[160a] D. Fournier,[116] H. Fox,[71] S. Fracchia,[12] P. Francavilla,[79]

M. Franchini,[20a,20b] S. Franchino,[30] D. Francis,[30] M. Franklin,[57] S. Franz,[61] M. Fraternali,[120a,120b] S. T. French,[28] C. Friedrich,[42] F. Friedrich,[44] D. Froidevaux,[30] J. A. Frost,[28] C. Fukunaga,[157] E. Fullana Torregrosa,[82] B. G. Fulsom,[144] J. Fuster,[168] C. Gabaldon,[55] O. Gabizon,[173] A. Gabrielli,[20a,20b] A. Gabrielli,[133a,133b] S. Gadatsch,[106] S. Gadomski,[49] G. Gagliardi,[50a,50b] P. Gagnon,[60] C. Galea,[105] B. Galhardo,[125a,125c] E. J. Gallas,[119] V. Gallo,[17] B. J. Gallop,[130] P. Gallus,[127] G. Galster,[36] K. K. Gan,[110] R. P. Gandrajula,[62] J. Gao,[33b,g] Y. S. Gao,[144,f] F. M. Garay Walls,[46] F. Garberson,[177] C. García,[168] J. E. García Navarro,[168] M. Garcia-Sciveres,[15] R. W. Gardner,[31] N. Garelli,[144] V. Garonne,[30] C. Gatti,[47] G. Gaudio,[120a] B. Gaur,[142] L. Gauthier,[94] P. Gauzzi,[133a,133b] I. L. Gavrilenko,[95] C. Gay,[169] G. Gaycken,[21] E. N. Gazis,[10] P. Ge,[33d] Z. Gecse,[169] C. N. P. Gee,[130] D. A. A. Geerts,[106] Ch. Geich-Gimbel,[21] K. Gellerstedt,[147a,147b] C. Gemme,[50a] A. Gemmell,[53] M. H. Genest,[55] S. Gentile,[133a,133b] M. George,[54] S. George,[76] D. Gerbaudo,[164] A. Gershon,[154] H. Ghazlane,[136b] N. Ghodbane,[34] B. Giacobbe,[20a] S. Giagu,[133a,133b] V. Giangiobbe,[12] P. Giannetti,[123a,123b] F. Gianotti,[30] B. Gibbard,[25] S. M. Gibson,[76] M. Gilchriese,[15] T. P. S. Gillam,[28] D. Gillberg,[30] G. Gilles,[34] D. M. Gingrich,[3,e] N. Giokaris,[9] M. P. Giordani,[165a,165c] R. Giordano,[103a,103b] F. M. Giorgi,[20a] F. M. Giorgi,[16] P. F. Giraud,[137] D. Giugni,[90a] C. Giuliani,[48] M. Giulini,[58b] B. K. Gjelsten,[118] S. Gkaitatzis,[155] I. Gkialas,[155,l] L. K. Gladilin,[98] C. Glasman,[81] J. Glatzer,[30] P. C. F. Glaysher,[46] A. Glazov,[42] G. L. Glonti,[64] M. Goblirsch-Kolb,[100] J. R. Goddard,[75] J. Godfrey,[143] J. Godlewski,[30] C. Goeringer,[82] S. Goldfarb,[88] T. Golling,[177] D. Golubkov,[129] A. Gomes,[125a,125b,125d] L. S. Gomez Fajardo,[42] R. Gonçalo,[125a] J. Goncalves Pinto Firmino Da Costa,[137] L. Gonella,[21] S. González de la Hoz,[168] G. Gonzalez Parra,[12] M. L. Gonzalez Silva,[27] S. Gonzalez-Sevilla,[49] L. Goossens,[30] P. A. Gorbounov,[96] H. A. Gordon,[25] I. Gorelov,[104] B. Gorini,[30] E. Gorini,[72a,72b] A. Gorišek,[74] E. Gornicki,[39] A. T. Goshaw,[6] C. Gössling,[43] M. I. Gostkin,[64] M. Gouighri,[136a] D. Goujdami,[136c] M. P. Goulette,[49] A. G. Goussiou,[139] C. Goy,[5] S. Gozpinar,[23] H. M. X. Grabas,[137] L. Graber,[54] I. Grabowska-Bold,[38a] P. Grafström,[20a,20b] K-J. Grahn,[42] J. Gramling,[49] E. Gramstad,[118] S. Grancagnolo,[16] V. Grassi,[149] V. Gratchev,[122] H. M. Gray,[30] E. Graziani,[135a] O. G. Grebenyuk,[122] Z. D. Greenwood,[78,m] K. Gregersen,[77] I. M. Gregor,[42] P. Grenier,[144] J. Griffiths,[8] A. A. Grillo,[138] K. Grimm,[71] S. Grinstein,[12,n] Ph. Gris,[34] Y. V. Grishkevich,[98] J.-F. Grivaz,[116] J. P. Grohs,[44] A. Grohsjean,[42] E. Gross,[173] J. Grosse-Knetter,[54] G. C. Grossi,[134a,134b] J. Groth-Jensen,[173] Z. J. Grout,[150] L. Guan,[33b] F. Guescini,[49] D. Guest,[177] O. Gueta,[154] C. Guicheney,[34] E. Guido,[50a,50b] T. Guillemin,[116] S. Guindon,[2] U. Gul,[53] C. Gumpert,[44] J. Gunther,[127] J. Guo,[35] S. Gupta,[119] P. Gutierrez,[112] N. G. Gutierrez Ortiz,[53] C. Gutschow,[77] N. Guttman,[154] C. Guyot,[137] C. Gwenlan,[119] C. B. Gwilliam,[73] A. Haas,[109] C. Haber,[15] H. K. Hadavand,[8] N. Haddad,[136e] P. Haefner,[21] S. Hageböck,[21] Z. Hajduk,[39] H. Hakobyan,[178] M. Haleem,[42] D. Hall,[119] G. Halladjian,[89] K. Hamacher,[176] P. Hamal,[114] K. Hamano,[170] M. Hamer,[54] A. Hamilton,[146a] S. Hamilton,[162] P. G. Hamnett,[42] L. Han,[33b] K. Hanagaki,[117] K. Hanawa,[156] M. Hance,[15] P. Hanke,[58a] R. Hanna,[137] J. B. Hansen,[36] J. D. Hansen,[36] P. H. Hansen,[36] K. Hara,[161] A. S. Hard,[174] T. Harenberg,[176] F. Hariri,[116] S. Harkusha,[91] D. Harper,[88] R. D. Harrington,[46] O. M. Harris,[139] P. F. Harrison,[171] F. Hartjes,[106] S. Hasegawa,[102] Y. Hasegawa,[141] A. Hasib,[112] S. Hassani,[137] S. Haug,[17] M. Hauschild,[30] R. Hauser,[89] M. Havranek,[126] C. M. Hawkes,[18] R. J. Hawkings,[30] A. D. Hawkins,[80] T. Hayashi,[161] D. Hayden,[89] C. P. Hays,[119] H. S. Hayward,[73] S. J. Haywood,[130] S. J. Head,[18] T. Heck,[82] V. Hedberg,[80] L. Heelan,[8] S. Heim,[121] T. Heim,[176] B. Heinemann,[15] L. Heinrich,[109] S. Heisterkamp,[36] J. Hejbal,[126] L. Helary,[22] C. Heller,[99] M. Heller,[30] S. Hellman,[147a,147b] D. Hellmich,[21] C. Helsens,[30] J. Henderson,[119] R. C. W. Henderson,[71] C. Hengler,[42] A. Henrichs,[177] A. M. Henriques Correia,[30] S. Henrot-Versille,[116] C. Hensel,[54] G. H. Herbert,[16] Y. Hernández Jiménez,[168] R. Herrberg-Schubert,[16] G. Herten,[48] R. Hertenberger,[99] L. Hervas,[30] G. G. Hesketh,[77] N. P. Hessey,[106] R. Hickling,[75] E. Higón-Rodriguez,[168] E. Hill,[170] J. C. Hill,[28] K. H. Hiller,[42] S. Hillert,[21] S. J. Hillier,[18] I. Hinchliffe,[15] E. Hines,[121] M. Hirose,[158] D. Hirschbuehl,[176] J. Hobbs,[149] N. Hod,[106] M. C. Hodgkinson,[140] P. Hodgson,[140] A. Hoecker,[30] M. R. Hoeferkamp,[104] J. Hoffman,[40] D. Hoffmann,[84] J. I. Hofmann,[58a] M. Hohlfeld,[82] T. R. Holmes,[15] T. M. Hong,[121] L. Hooft van Huysduynen,[109] J-Y. Hostachy,[55] S. Hou,[152] A. Hoummada,[136a] J. Howard,[119] J. Howarth,[42] M. Hrabovsky,[114] I. Hristova,[16] J. Hrivnac,[116] T. Hryn'ova,[5] P. J. Hsu,[82] S.-C. Hsu,[139] D. Hu,[35] X. Hu,[25] Y. Huang,[42] Z. Hubacek,[30] F. Hubaut,[84] F. Huegging,[21] T. B. Huffman,[119] E. W. Hughes,[35] G. Hughes,[71] M. Huhtinen,[30] T. A. Hülsing,[82] M. Hurwitz,[15] N. Huseynov,[64,c] J. Huston,[89] J. Huth,[57] G. Iacobucci,[49] G. Iakovidis,[10] I. Ibragimov,[142] L. Iconomidou-Fayard,[116] E. Ideal,[177] P. Iengo,[103a] O. Igonkina,[106] T. Iizawa,[172] Y. Ikegami,[65] K. Ikematsu,[142] M. Ikeno,[65] Y. Ilchenko,[31,aa] D. Iliadis,[155] N. Ilic,[159] Y. Inamaru,[66] T. Ince,[100] P. Ioannou,[9] M. Iodice,[135a] K. Iordanidou,[9] V. Ippolito,[57] A. Irles Quiles,[168] C. Isaksson,[167] M. Ishino,[67] M. Ishitsuka,[158] R. Ishmukhametov,[110] C. Issever,[119] S. Istin,[19a] J. M. Iturbe Ponce,[83] R. Iuppa,[134a,134b] J. Ivarsson,[80] W. Iwanski,[39] H. Iwasaki,[65] J. M. Izen,[41] V. Izzo,[103a] B. Jackson,[121] M. Jackson,[73] P. Jackson,[1] M. R. Jaekel,[30] V. Jain,[2] K. Jakobs,[48] S. Jakobsen,[30] T. Jakoubek,[126] J. Jakubek,[127] D. O. Jamin,[152] D. K. Jana,[78] E. Jansen,[77] H. Jansen,[30]

J. Janssen,[21] M. Janus,[171] G. Jarlskog,[80] N. Javadov,[64,c] T. Javůrek,[48] L. Jeanty,[15] J. Jejelava,[51a,o] G.-Y. Jeng,[151] D. Jennens,[87] P. Jenni,[48,p] J. Jentzsch,[43] C. Jeske,[171] S. Jézéquel,[5] H. Ji,[174] W. Ji,[82] J. Jia,[149] Y. Jiang,[33b] M. Jimenez Belenguer,[42] S. Jin,[33a] A. Jinaru,[26a] O. Jinnouchi,[158] M. D. Joergensen,[36] K. E. Johansson,[147a] P. Johansson,[140] K. A. Johns,[7] K. Jon-And,[147a,147b] G. Jones,[171] R. W. L. Jones,[71] T. J. Jones,[73] J. Jongmanns,[58a] P. M. Jorge,[125a,125b] K. D. Joshi,[83] J. Jovicevic,[148] X. Ju,[174] C. A. Jung,[43] R. M. Jungst,[30] P. Jussel,[61] A. Juste Rozas,[12,n] M. Kaci,[168] A. Kaczmarska,[39] M. Kado,[116] H. Kagan,[110] M. Kagan,[144] E. Kajomovitz,[45] C. W. Kalderon,[119] S. Kama,[40] N. Kanaya,[156] M. Kaneda,[30] S. Kaneti,[28] T. Kanno,[158] V. A. Kantserov,[97] J. Kanzaki,[65] B. Kaplan,[109] A. Kapliy,[31] D. Kar,[53] K. Karakostas,[10] N. Karastathis,[10] M. Karnevskiy,[82] S. N. Karpov,[64] K. Karthik,[109] V. Kartvelishvili,[71] A. N. Karyukhin,[129] L. Kashif,[174] G. Kasieczka,[58b] R. D. Kass,[110] A. Kastanas,[14] Y. Kataoka,[156] A. Katre,[49] J. Katzy,[42] V. Kaushik,[7] K. Kawagoe,[69] T. Kawamoto,[156] G. Kawamura,[54] S. Kazama,[156] V. F. Kazanin,[108] M. Y. Kazarinov,[64] R. Keeler,[170] R. Kehoe,[40] M. Keil,[54] J. S. Keller,[42] J. J. Kempster,[76] H. Keoshkerian,[5] O. Kepka,[126] B. P. Kerševan,[74] S. Kersten,[176] K. Kessoku,[156] J. Keung,[159] F. Khalil-zada,[11] H. Khandanyan,[147a,147b] A. Khanov,[113] A. Khodinov,[97] A. Khomich,[58a] T. J. Khoo,[28] G. Khoriauli,[21] A. Khoroshilov,[176] V. Khovanskiy,[96] E. Khramov,[64] J. Khubua,[51b] H. Y. Kim,[8] H. Kim,[147a,147b] S. H. Kim,[161] N. Kimura,[172] O. Kind,[16] B. T. King,[73] M. King,[168] R. S. B. King,[119] S. B. King,[169] J. Kirk,[130] A. E. Kiryunin,[100] T. Kishimoto,[66] D. Kisielewska,[38a] F. Kiss,[48] T. Kitamura,[66] T. Kittelmann,[124] K. Kiuchi,[161] E. Kladiva,[145b] M. Klein,[73] U. Klein,[73] K. Kleinknecht,[82] P. Klimek,[147a,147b] A. Klimentov,[25] R. Klingenberg,[43] J. A. Klinger,[83] T. Klioutchnikova,[30] P. F. Klok,[105] E.-E. Kluge,[58a] P. Kluit,[106] S. Kluth,[100] E. Kneringer,[61] E. B. F. G. Knoops,[84] A. Knue,[53] T. Kobayashi,[156] M. Kobel,[44] M. Kocian,[144] P. Kodys,[128] P. Koevesarki,[21] T. Koffas,[29] E. Koffeman,[106] L. A. Kogan,[119] S. Kohlmann,[176] Z. Kohout,[127] T. Kohriki,[65] T. Koi,[144] H. Kolanoski,[16] I. Koletsou,[5] J. Koll,[89] A. A. Komar,[95,a] Y. Komori,[156] T. Kondo,[65] N. Kondrashova,[42] K. Köneke,[48] A. C. König,[105] S. König,[82] T. Kono,[65,q] R. Konoplich,[109,r] N. Konstantinidis,[77] R. Kopeliansky,[153] S. Koperny,[38a] L. Köpke,[82] A. K. Kopp,[48] K. Korcyl,[39] K. Kordas,[155] A. Korn,[77] A. A. Korol,[108,s] I. Korolkov,[12] E. V. Korolkova,[140] V. A. Korotkov,[129] O. Kortner,[100] S. Kortner,[100] V. V. Kostyukhin,[21] V. M. Kotov,[64] A. Kotwal,[45] C. Kourkoumelis,[9] V. Kouskoura,[155] A. Koutsman,[160a] R. Kowalewski,[170] T. Z. Kowalski,[38a] W. Kozanecki,[137] A. S. Kozhin,[129] V. Kral,[127] V. A. Kramarenko,[98] G. Kramberger,[74] D. Krasnopevtsev,[97] M. W. Krasny,[79] A. Krasznahorkay,[30] J. K. Kraus,[21] A. Kravchenko,[25] S. Kreiss,[109] M. Kretz,[58c] J. Kretzschmar,[73] K. Kreutzfeldt,[52] P. Krieger,[159] K. Kroeninger,[54] H. Kroha,[100] J. Kroll,[121] J. Kroseberg,[21] J. Krstic,[13a] U. Kruchonak,[64] H. Krüger,[21] T. Kruker,[17] N. Krumnack,[63] Z. V. Krumshteyn,[64] A. Kruse,[174] M. C. Kruse,[45] M. Kruskal,[22] T. Kubota,[87] S. Kuday,[4a] S. Kuehn,[48] A. Kugel,[58c] A. Kuhl,[138] T. Kuhl,[42] V. Kukhtin,[64] Y. Kulchitsky,[91] S. Kuleshov,[32b] M. Kuna,[133a,133b] J. Kunkle,[121] A. Kupco,[126] H. Kurashige,[66] Y. A. Kurochkin,[91] R. Kurumida,[66] V. Kus,[126] E. S. Kuwertz,[148] M. Kuze,[158] J. Kvita,[114] A. La Rosa,[49] L. La Rotonda,[37a,37b] C. Lacasta,[168] F. Lacava,[133a,133b] J. Lacey,[29] H. Lacker,[16] D. Lacour,[79] V. R. Lacuesta,[168] E. Ladygin,[64] R. Lafaye,[5] B. Laforge,[79] T. Lagouri,[177] S. Lai,[48] H. Laier,[58a] L. Lambourne,[77] S. Lammers,[60] C. L. Lampen,[7] W. Lampl,[7] E. Lançon,[137] U. Landgraf,[48] M. P. J. Landon,[75] V. S. Lang,[58a] C. Lange,[42] A. J. Lankford,[164] F. Lanni,[25] K. Lantzsch,[30] S. Laplace,[79] C. Lapoire,[21] J. F. Laporte,[137] T. Lari,[90a] M. Lassnig,[30] P. Laurelli,[47] W. Lavrijsen,[15] A. T. Law,[138] P. Laycock,[73] B. T. Le,[55] O. Le Dortz,[79] E. Le Guirriec,[84] E. Le Menedeu,[12] T. LeCompte,[6] F. Ledroit-Guillon,[55] C. A. Lee,[152] H. Lee,[106] J. S. H. Lee,[117] S. C. Lee,[152] L. Lee,[177] G. Lefebvre,[79] M. Lefebvre,[170] F. Legger,[99] C. Leggett,[15] A. Lehan,[73] M. Lehmacher,[21] G. Lehmann Miotto,[30] X. Lei,[7] W. A. Leight,[29] A. Leisos,[155] A. G. Leister,[177] M. A. L. Leite,[24d] R. Leitner,[128] D. Lellouch,[173] B. Lemmer,[54] K. J. C. Leney,[77] T. Lenz,[106] G. Lenzen,[176] B. Lenzi,[30] R. Leone,[7] K. Leonhardt,[44] S. Leontsinis,[10] C. Leroy,[94] C. G. Lester,[28] C. M. Lester,[121] M. Levchenko,[122] J. Levêque,[5] D. Levin,[88] L. J. Levinson,[173] M. Levy,[18] A. Lewis,[119] G. H. Lewis,[109] A. M. Leyko,[21] M. Leyton,[41] B. Li,[33b,t] B. Li,[84] H. Li,[149] H. L. Li,[31] L. Li,[45] L. Li,[33e] S. Li,[45] Y. Li,[33c,u] Z. Liang,[138] H. Liao,[34] B. Liberti,[134a] P. Lichard,[30] K. Lie,[166] J. Liebal,[21] W. Liebig,[14] C. Limbach,[21] A. Limosani,[87] S. C. Lin,[152,v] T. H. Lin,[82] F. Linde,[106] B. E. Lindquist,[149] J. T. Linnemann,[89] E. Lipeles,[121] A. Lipniacka,[14] M. Lisovyi,[42] T. M. Liss,[166] D. Lissauer,[25] A. Lister,[169] A. M. Litke,[138] B. Liu,[152] D. Liu,[152] J. B. Liu,[33b] K. Liu,[33b,w] L. Liu,[88] M. Liu,[45] M. Liu,[33b] Y. Liu,[33b] M. Livan,[120a,120b] S. S. A. Livermore,[119] A. Lleres,[55] J. Llorente Merino,[81] S. L. Lloyd,[75] F. Lo Sterzo,[152] E. Lobodzinska,[42] P. Loch,[7] W. S. Lockman,[138] T. Loddenkoetter,[21] F. K. Loebinger,[83] A. E. Loevschall-Jensen,[36] A. Loginov,[177] C. W. Loh,[169] T. Lohse,[16] K. Lohwasser,[42] M. Lokajicek,[126] V. P. Lombardo,[5] B. A. Long,[22] J. D. Long,[88] R. E. Long,[71] L. Lopes,[125a] D. Lopez Mateos,[57] B. Lopez Paredes,[140] I. Lopez Paz,[12] J. Lorenz,[99] N. Lorenzo Martinez,[60] M. Losada,[163] P. Loscutoff,[15] X. Lou,[41] A. Lounis,[116] J. Love,[6] P. A. Love,[71] A. J. Lowe,[144,f] F. Lu,[33a] H. J. Lubatti,[139] C. Luci,[133a,133b] A. Lucotte,[55] F. Luehring,[60] W. Lukas,[61] L. Luminari,[133a] O. Lundberg,[147a,147b] B. Lund-Jensen,[148] M. Lungwitz,[82] D. Lynn,[25] R. Lysak,[126] E. Lytken,[80]

H. Ma,[25] L. L. Ma,[33d] G. Maccarrone,[47] A. Macchiolo,[100] J. Machado Miguens,[125a,125b] D. Macina,[30] D. Madaffari,[84] R. Madar,[48] H. J. Maddocks,[71] W. F. Mader,[44] A. Madsen,[167] M. Maeno,[8] T. Maeno,[25] E. Magradze,[54] K. Mahboubi,[48] J. Mahlstedt,[106] S. Mahmoud,[73] C. Maiani,[137] C. Maidantchik,[24a] A. Maio,[125a,125b,125d] S. Majewski,[115] Y. Makida,[65] N. Makovec,[116] P. Mal,[137,x] B. Malaescu,[79] Pa. Malecki,[39] V. P. Maleev,[122] F. Malek,[55] U. Mallik,[62] D. Malon,[6] C. Malone,[144] S. Maltezos,[10] V. M. Malyshev,[108] S. Malyukov,[30] J. Mamuzic,[13b] B. Mandelli,[30] L. Mandelli,[90a] I. Mandić,[74] R. Mandrysch,[62] J. Maneira,[125a,125b] A. Manfredini,[100] L. Manhaes de Andrade Filho,[24b] J. A. Manjarres Ramos,[160b] A. Mann,[99] P. M. Manning,[138] A. Manousakis-Katsikakis,[9] B. Mansoulie,[137] R. Mantifel,[86] L. Mapelli,[30] L. March,[168] J. F. Marchand,[29] G. Marchiori,[79] M. Marcisovsky,[126] C. P. Marino,[170] M. Marjanovic,[13a] C. N. Marques,[125a] F. Marroquim,[24a] S. P. Marsden,[83] Z. Marshall,[15] L. F. Marti,[17] S. Marti-Garcia,[168] B. Martin,[30] B. Martin,[89] T. A. Martin,[171] V. J. Martin,[46] B. Martin dit Latour,[14] H. Martinez,[137] M. Martinez,[12,n] S. Martin-Haugh,[130] A. C. Martyniuk,[77] M. Marx,[139] F. Marzano,[133a] A. Marzin,[30] L. Masetti,[82] T. Mashimo,[156] R. Mashinistov,[95] J. Masik,[83] A. L. Maslennikov,[108] I. Massa,[20a,20b] N. Massol,[5] P. Mastrandrea,[149] A. Mastroberardino,[37a,37b] T. Masubuchi,[156] T. Matsushita,[66] P. Mättig,[176] S. Mättig,[42] J. Mattmann,[82] J. Maurer,[26a] S. J. Maxfield,[73] D. A. Maximov,[108,s] R. Mazini,[152] L. Mazzaferro,[134a,134b] G. Mc Goldrick,[159] S. P. Mc Kee,[88] A. McCarn,[88] R. L. McCarthy,[149] T. G. McCarthy,[29] N. A. McCubbin,[130] K. W. McFarlane,[56,a] J. A. Mcfayden,[77] G. Mchedlidze,[54] S. J. McMahon,[130] R. A. McPherson,[170,i] A. Meade,[85] J. Mechnich,[106] M. Medinnis,[42] S. Meehan,[31] S. Mehlhase,[36] A. Mehta,[73] K. Meier,[58a] C. Meineck,[99] B. Meirose,[80] C. Melachrinos,[31] B. R. Mellado Garcia,[146c] F. Meloni,[90a,90b] A. Mengarelli,[20a,20b] S. Menke,[100] E. Meoni,[162] K. M. Mercurio,[57] S. Mergelmeyer,[21] N. Meric,[137] P. Mermod,[49] L. Merola,[103a,103b] C. Meroni,[90a] F. S. Merritt,[31] H. Merritt,[110] A. Messina,[30,y] J. Metcalfe,[25] A. S. Mete,[164] C. Meyer,[82] C. Meyer,[31] J-P. Meyer,[137] J. Meyer,[30] R. P. Middleton,[130] S. Migas,[73] L. Mijović,[21] G. Mikenberg,[173] M. Mikestikova,[126] M. Mikuž,[74] D. W. Miller,[31] C. Mills,[46] A. Milov,[173] D. A. Milstead,[147a,147b] D. Milstein,[173] A. A. Minaenko,[129] I. A. Minashvili,[64] A. I. Mincer,[109] B. Mindur,[38a] M. Mineev,[64] Y. Ming,[174] L. M. Mir,[12] G. Mirabelli,[133a] T. Mitani,[172] J. Mitrevski,[99] V. A. Mitsou,[168] S. Mitsui,[65] A. Miucci,[49] P. S. Miyagawa,[140] J. U. Mjörnmark,[80] T. Moa,[147a,147b] K. Mochizuki,[84] V. Moeller,[28] S. Mohapatra,[35] W. Mohr,[48] S. Molander,[147a,147b] R. Moles-Valls,[168] K. Mönig,[42] C. Monini,[55] J. Monk,[36] E. Monnier,[84] J. Montejo Berlingen,[12] F. Monticelli,[70] S. Monzani,[133a,133b] R. W. Moore,[3] A. Moraes,[53] N. Morange,[62] D. Moreno,[82] M. Moreno Llácer,[54] P. Morettini,[50a] M. Morgenstern,[44] M. Morii,[57] S. Moritz,[82] A. K. Morley,[148] G. Mornacchi,[30] J. D. Morris,[75] L. Morvaj,[102] H. G. Moser,[100] M. Mosidze,[51b] J. Moss,[110] R. Mount,[144] E. Mountricha,[25] S. V. Mouraviev,[95,a] E. J. W. Moyse,[85] S. Muanza,[84] R. D. Mudd,[18] F. Mueller,[58a] J. Mueller,[124] K. Mueller,[21] T. Mueller,[28] T. Mueller,[82] D. Muenstermann,[49] Y. Munwes,[154] J. A. Murillo Quijada,[18] W. J. Murray,[171,130] H. Musheghyan,[54] E. Musto,[153] A. G. Myagkov,[129,z] M. Myska,[127] O. Nackenhorst,[54] J. Nadal,[54] K. Nagai,[61] R. Nagai,[158] Y. Nagai,[84] K. Nagano,[65] A. Nagarkar,[110] Y. Nagasaka,[59] M. Nagel,[100] A. M. Nairz,[30] Y. Nakahama,[30] K. Nakamura,[65] T. Nakamura,[156] I. Nakano,[111] H. Namasivayam,[41] G. Nanava,[21] R. Narayan,[58b] T. Nattermann,[21] T. Naumann,[42] G. Navarro,[163] R. Nayyar,[7] H. A. Neal,[88] P. Yu. Nechaeva,[95] T. J. Neep,[83] A. Negri,[120a,120b] G. Negri,[30] M. Negrini,[20a] S. Nektarijevic,[49] A. Nelson,[164] T. K. Nelson,[144] S. Nemecek,[126] P. Nemethy,[109] A. A. Nepomuceno,[24a] M. Nessi,[30,bb] M. S. Neubauer,[166] M. Neumann,[176] R. M. Neves,[109] P. Nevski,[25] P. R. Newman,[18] D. H. Nguyen,[6] R. B. Nickerson,[119] R. Nicolaidou,[137] B. Nicquevert,[30] J. Nielsen,[138] N. Nikiforou,[35] A. Nikiforov,[16] V. Nikolaenko,[129,z] I. Nikolic-Audit,[79] K. Nikolics,[49] K. Nikolopoulos,[18] P. Nilsson,[8] Y. Ninomiya,[156] A. Nisati,[133a] R. Nisius,[100] T. Nobe,[158] L. Nodulman,[6] M. Nomachi,[117] I. Nomidis,[155] S. Norberg,[112] M. Nordberg,[30] S. Nowak,[100] M. Nozaki,[65] L. Nozka,[114] K. Ntekas,[10] G. Nunes Hanninger,[87] T. Nunnemann,[99] E. Nurse,[77] F. Nuti,[87] B. J. O'Brien,[46] F. O'grady,[7] D. C. O'Neil,[143] V. O'Shea,[53] F. G. Oakham,[29,e] H. Oberlack,[100] T. Obermann,[21] J. Ocariz,[79] A. Ochi,[66] M. I. Ochoa,[77] S. Oda,[69] S. Odaka,[65] H. Ogren,[60] A. Oh,[83] S. H. Oh,[45] C. C. Ohm,[30] H. Ohman,[167] T. Ohshima,[102] W. Okamura,[117] H. Okawa,[25] Y. Okumura,[31] T. Okuyama,[156] A. Olariu,[26a] A. G. Olchevski,[64] S. A. Olivares Pino,[46] D. Oliveira Damazio,[25] E. Oliver Garcia,[168] A. Olszewski,[39] J. Olszowska,[39] A. Onofre,[125a,125e] P. U. E. Onyisi,[31,aa] C. J. Oram,[160a] M. J. Oreglia,[31] Y. Oren,[154] D. Orestano,[135a,135b] N. Orlando,[72a,72b] C. Oropeza Barrera,[53] R. S. Orr,[159] B. Osculati,[50a,50b] R. Ospanov,[121] G. Otero y Garzon,[27] H. Otono,[69] M. Ouchrif,[136d] E. A. Ouellette,[170] F. Ould-Saada,[118] A. Ouraou,[137] K. P. Oussoren,[106] Q. Ouyang,[33a] A. Ovcharova,[15] M. Owen,[83] V. E. Ozcan,[19a] N. Ozturk,[8] K. Pachal,[119] A. Pacheco Pages,[12] C. Padilla Aranda,[12] M. Pagáčová,[48] S. Pagan Griso,[15] E. Paganis,[140] C. Pahl,[100] F. Paige,[25] P. Pais,[85] K. Pajchel,[118] G. Palacino,[160b] S. Palestini,[30] M. Palka,[38b] D. Pallin,[34] A. Palma,[125a,125b] J. D. Palmer,[18] Y. B. Pan,[174] E. Panagiotopoulou,[10] J. G. Panduro Vazquez,[76] P. Pani,[106] N. Panikashvili,[88] S. Panitkin,[25] D. Pantea,[26a] L. Paolozzi,[134a,134b] Th. D. Papadopoulou,[10] K. Papageorgiou,[155,l] A. Paramonov,[6] D. Paredes Hernandez,[34] M. A. Parker,[28]

F. Parodi,[50a,50b] J. A. Parsons,[35] U. Parzefall,[48] E. Pasqualucci,[133a] S. Passaggio,[50a] A. Passeri,[135a] F. Pastore,[135a,135b,a] Fr. Pastore,[76] G. Pásztor,[29] S. Pataraia,[176] N. D. Patel,[151] J. R. Pater,[83] S. Patricelli,[103a,103b] T. Pauly,[30] J. Pearce,[170] M. Pedersen,[118] S. Pedraza Lopez,[168] R. Pedro,[125a,125b] S. V. Peleganchuk,[108] D. Pelikan,[167] H. Peng,[33b] B. Penning,[31] J. Penwell,[60] D. V. Perepelitsa,[25] E. Perez Codina,[160a] M. T. Pérez García-Estañ,[168] V. Perez Reale,[35] L. Perini,[90a,90b] H. Pernegger,[30] R. Perrino,[72a] R. Peschke,[42] V. D. Peshekhonov,[64] K. Peters,[30] R. F. Y. Peters,[83] B. A. Petersen,[30] T. C. Petersen,[36] E. Petit,[42] A. Petridis,[147a,147b] C. Petridou,[155] E. Petrolo,[133a] F. Petrucci,[135a,135b] M. Petteni,[143] N. E. Pettersson,[158] R. Pezoa,[32b] P. W. Phillips,[130] G. Piacquadio,[144] E. Pianori,[171] A. Picazio,[49] E. Piccaro,[75] M. Piccinini,[20a,20b] R. Piegaia,[27] D. T. Pignotti,[110] J. E. Pilcher,[31] A. D. Pilkington,[77] J. Pina,[125a,125b,125d] M. Pinamonti,[165a,165c,cc] A. Pinder,[119] J. L. Pinfold,[3] A. Pingel,[36] B. Pinto,[125a] S. Pires,[79] M. Pitt,[173] C. Pizio,[90a,90b] L. Plazak,[145a] M.-A. Pleier,[25] V. Pleskot,[128] E. Plotnikova,[64] P. Plucinski,[147a,147b] S. Poddar,[58a] F. Podlyski,[34] R. Poettgen,[82] L. Poggioli,[116] D. Pohl,[21] M. Pohl,[49] G. Polesello,[120a] A. Policicchio,[37a,37b] R. Polifka,[159] A. Polini,[20a] C. S. Pollard,[45] V. Polychronakos,[25] K. Pommès,[30] L. Pontecorvo,[133a] B. G. Pope,[89] G. A. Popeneciu,[26b] D. S. Popovic,[13a] A. Poppleton,[30] X. Portell Bueso,[12] G. E. Pospelov,[100] S. Pospisil,[127] K. Potamianos,[15] I. N. Potrap,[64] C. J. Potter,[150] C. T. Potter,[115] G. Poulard,[30] J. Poveda,[60] V. Pozdnyakov,[64] P. Pralavorio,[84] A. Pranko,[15] S. Prasad,[30] R. Pravahan,[8] S. Prell,[63] D. Price,[83] J. Price,[73] L. E. Price,[6] D. Prieur,[124] M. Primavera,[72a] M. Proissl,[46] K. Prokofiev,[47] F. Prokoshin,[32b] E. Protopapadaki,[137] S. Protopopescu,[25] J. Proudfoot,[6] M. Przybycien,[38a] H. Przysiezniak,[5] E. Ptacek,[115] E. Pueschel,[85] D. Puldon,[149] M. Purohit,[25,dd] P. Puzo,[116] J. Qian,[88] G. Qin,[53] Y. Qin,[83] A. Quadt,[54] D. R. Quarrie,[15] W. B. Quayle,[165a,165b] M. Queitsch-Maitland,[83] D. Quilty,[53] A. Qureshi,[160b] V. Radeka,[25] V. Radescu,[42] S. K. Radhakrishnan,[149] P. Radloff,[115] P. Rados,[87] F. Ragusa,[90a,90b] G. Rahal,[179] S. Rajagopalan,[25] M. Rammensee,[30] A. S. Randle-Conde,[40] C. Rangel-Smith,[167] K. Rao,[164] F. Rauscher,[99] T. C. Rave,[48] T. Ravenscroft,[53] M. Raymond,[30] A. L. Read,[118] N. P. Readioff,[73] D. M. Rebuzzi,[120a,120b] A. Redelbach,[175] G. Redlinger,[25] R. Reece,[138] K. Reeves,[41] L. Rehnisch,[16] H. Reisin,[27] M. Relich,[164] C. Rembser,[30] H. Ren,[33a] Z. L. Ren,[152] A. Renaud,[116] M. Rescigno,[133a] S. Resconi,[90a] O. L. Rezanova,[108,s] P. Reznicek,[128] R. Rezvani,[94] R. Richter,[100] M. Ridel,[79] P. Rieck,[16] J. Rieger,[54] M. Rijssenbeek,[149] A. Rimoldi,[120a,120b] L. Rinaldi,[20a] E. Ritsch,[61] I. Riu,[12] F. Rizatdinova,[113] E. Rizvi,[75] S. H. Robertson,[86,i] A. Robichaud-Veronneau,[86] D. Robinson,[28] J. E. M. Robinson,[83] A. Robson,[53] C. Roda,[123a,123b] L. Rodrigues,[30] S. Roe,[30] O. Røhne,[118] S. Rolli,[162] A. Romaniouk,[97] M. Romano,[20a,20b] G. Romeo,[27] E. Romero Adam,[168] N. Rompotis,[139] L. Roos,[79] E. Ros,[168] S. Rosati,[133a] K. Rosbach,[49] M. Rose,[76] P. L. Rosendahl,[14] O. Rosenthal,[142] V. Rossetti,[147a,147b] E. Rossi,[103a,103b] L. P. Rossi,[50a] R. Rosten,[139] M. Rotaru,[26a] I. Roth,[173] J. Rothberg,[139] D. Rousseau,[116] C. R. Royon,[137] A. Rozanov,[84] Y. Rozen,[153] X. Ruan,[146c] F. Rubbo,[12] I. Rubinskiy,[42] V. I. Rud,[98] C. Rudolph,[44] M. S. Rudolph,[159] F. Rühr,[48] A. Ruiz-Martinez,[30] Z. Rurikova,[48] N. A. Rusakovich,[64] A. Ruschke,[99] J. P. Rutherfoord,[7] N. Ruthmann,[48] Y. F. Ryabov,[122] M. Rybar,[128] G. Rybkin,[116] N. C. Ryder,[119] A. F. Saavedra,[151] S. Sacerdoti,[27] A. Saddique,[3] I. Sadeh,[154] H. F-W. Sadrozinski,[138] R. Sadykov,[64] F. Safai Tehrani,[133a] H. Sakamoto,[156] Y. Sakurai,[172] G. Salamanna,[75] A. Salamon,[134a] M. Saleem,[112] D. Salek,[106] P. H. Sales De Bruin,[139] D. Salihagic,[100] A. Salnikov,[144] J. Salt,[168] B. M. Salvachua Ferrando,[6] D. Salvatore,[37a,37b] F. Salvatore,[150] A. Salvucci,[105] A. Salzburger,[30] D. Sampsonidis,[155] A. Sanchez,[103a,103b] J. Sánchez,[168] V. Sanchez Martinez,[168] H. Sandaker,[14] R. L. Sandbach,[75] H. G. Sander,[82] M. P. Sanders,[99] M. Sandhoff,[176] T. Sandoval,[28] C. Sandoval,[163] R. Sandstroem,[100] D. P. C. Sankey,[130] A. Sansoni,[47] C. Santoni,[34] R. Santonico,[134a,134b] H. Santos,[125a] I. Santoyo Castillo,[150] K. Sapp,[124] A. Sapronov,[64] J. G. Saraiva,[125a,125d] B. Sarrazin,[21] G. Sartisohn,[176] O. Sasaki,[65] Y. Sasaki,[156] G. Sauvage,[5,a] E. Sauvan,[5] P. Savard,[159,e] D. O. Savu,[30] C. Sawyer,[119] L. Sawyer,[78,m] D. H. Saxon,[53] J. Saxon,[121] C. Sbarra,[20a] A. Sbrizzi,[3] T. Scanlon,[77] D. A. Scannicchio,[164] M. Scarcella,[151] J. Schaarschmidt,[173] P. Schacht,[100] D. Schaefer,[121] R. Schaefer,[42] S. Schaepe,[21] S. Schaetzel,[58b] U. Schäfer,[82] A. C. Schaffer,[116] D. Schaile,[99] R. D. Schamberger,[149] V. Scharf,[58a] V. A. Schegelsky,[122] D. Scheirich,[128] M. Schernau,[164] M. I. Scherzer,[35] C. Schiavi,[50a,50b] J. Schieck,[99] C. Schillo,[48] M. Schioppa,[37a,37b] S. Schlenker,[30] E. Schmidt,[48] K. Schmieden,[30] C. Schmitt,[82] C. Schmitt,[99] S. Schmitt,[58b] B. Schneider,[17] Y. J. Schnellbach,[73] U. Schnoor,[44] L. Schoeffel,[137] A. Schoening,[58b] B. D. Schoenrock,[89] A. L. S. Schorlemmer,[54] M. Schott,[82] D. Schouten,[160a] J. Schovancova,[25] S. Schramm,[159] M. Schreyer,[175] C. Schroeder,[82] N. Schuh,[82] M. J. Schultens,[21] H.-C. Schultz-Coulon,[58a] H. Schulz,[16] M. Schumacher,[48] B. A. Schumm,[138] Ph. Schune,[137] C. Schwanenberger,[83] A. Schwartzman,[144] Ph. Schwegler,[100] Ph. Schwemling,[137] R. Schwienhorst,[89] J. Schwindling,[137] T. Schwindt,[21] M. Schwoerer,[5] F. G. Sciacca,[17] E. Scifo,[116] G. Sciolla,[23] W. G. Scott,[130] F. Scuri,[123a,123b] F. Scutti,[21] J. Searcy,[88] G. Sedov,[42] E. Sedykh,[122] S. C. Seidel,[104] A. Seiden,[138] F. Seifert,[127] J. M. Seixas,[24a] G. Sekhniaidze,[103a] S. J. Sekula,[40] K. E. Selbach,[46] D. M. Seliverstov,[122,a] G. Sellers,[73] N. Semprini-Cesari,[20a,20b] C. Serfon,[30] L. Serin,[116]

L. Serkin,[54] T. Serre,[84] R. Seuster,[160a] H. Severini,[112] F. Sforza,[100] A. Sfyrla,[30] E. Shabalina,[54] M. Shamim,[115] L. Y. Shan,[33a] R. Shang,[166] J. T. Shank,[22] Q. T. Shao,[87] M. Shapiro,[15] P. B. Shatalov,[96] K. Shaw,[165a,165b] C. Y. Shehu,[150] P. Sherwood,[77] L. Shi,[152,ee] S. Shimizu,[66] C. O. Shimmin,[164] M. Shimojima,[101] M. Shiyakova,[64] A. Shmeleva,[95] M. J. Shochet,[31] D. Short,[119] S. Shrestha,[63] E. Shulga,[97] M. A. Shupe,[7] S. Shushkevich,[42] P. Sicho,[126] O. Sidiropoulou,[155] D. Sidorov,[113] A. Sidoti,[133a] F. Siegert,[44] Dj. Sijacki,[13a] J. Silva,[125a,125d] Y. Silver,[154] D. Silverstein,[144] S. B. Silverstein,[147a] V. Simak,[127] O. Simard,[5] Lj. Simic,[13a] S. Simion,[116] E. Simioni,[82] B. Simmons,[77] R. Simoniello,[90a,90b] M. Simonyan,[36] P. Sinervo,[159] N. B. Sinev,[115] V. Sipica,[142] G. Siragusa,[175] A. Sircar,[78] A. N. Sisakyan,[64,a] S. Yu. Sivoklokov,[98] J. Sjölin,[147a,147b] T. B. Sjursen,[14] H. P. Skottowe,[57] K. Yu. Skovpen,[108] P. Skubic,[112] M. Slater,[18] T. Slavicek,[127] K. Sliwa,[162] V. Smakhtin,[173] B. H. Smart,[46] L. Smestad,[14] S. Yu. Smirnov,[97] Y. Smirnov,[97] L. N. Smirnova,[98,ff] O. Smirnova,[80] K. M. Smith,[53] M. Smizanska,[71] K. Smolek,[127] A. A. Snesarev,[95] G. Snidero,[75] S. Snyder,[25] R. Sobie,[170,i] F. Socher,[44] A. Soffer,[154] D. A. Soh,[152,ee] C. A. Solans,[30] M. Solar,[127] J. Solc,[127] E. Yu. Soldatov,[97] U. Soldevila,[168] E. Solfaroli Camillocci,[133a,133b] A. A. Solodkov,[129] A. Soloshenko,[64] O. V. Solovyanov,[129] V. Solovyev,[122] P. Sommer,[48] H. Y. Song,[33b] N. Soni,[1] A. Sood,[15] A. Sopczak,[127] B. Sopko,[127] V. Sopko,[127] V. Sorin,[12] M. Sosebee,[8] R. Soualah,[165a,165c] P. Soueid,[94] A. M. Soukharev,[108] D. South,[42] S. Spagnolo,[72a,72b] F. Spanò,[76] W. R. Spearman,[57] R. Spighi,[20a] G. Spigo,[30] M. Spousta,[128] T. Spreitzer,[159] B. Spurlock,[8] R. D. St. Denis,[53,a] S. Staerz,[44] J. Stahlman,[121] R. Stamen,[58a] E. Stanecka,[39] R. W. Stanek,[6] C. Stanescu,[135a] M. Stanescu-Bellu,[42] M. M. Stanitzki,[42] S. Stapnes,[118] E. A. Starchenko,[129] J. Stark,[55] P. Staroba,[126] P. Starovoitov,[42] R. Staszewski,[39] P. Stavina,[145a,a] P. Steinberg,[25] B. Stelzer,[143] H. J. Stelzer,[30] O. Stelzer-Chilton,[160a] H. Stenzel,[52] S. Stern,[100] G. A. Stewart,[53] J. A. Stillings,[21] M. C. Stockton,[86] M. Stoebe,[86] G. Stoicea,[26a] P. Stolte,[54] S. Stonjek,[100] A. R. Stradling,[8] A. Straessner,[44] M. E. Stramaglia,[17] J. Strandberg,[148] S. Strandberg,[147a,147b] A. Strandlie,[118] E. Strauss,[144] M. Strauss,[112] P. Strizenec,[145b] R. Ströhmer,[175] D. M. Strom,[115] R. Stroynowski,[40] S. A. Stucci,[17] B. Stugu,[14] N. A. Styles,[42] D. Su,[144] J. Su,[124] HS. Subramania,[3] R. Subramaniam,[78] A. Succurro,[12] Y. Sugaya,[117] C. Suhr,[107] M. Suk,[127] V. V. Sulin,[95] S. Sultansoy,[4c] T. Sumida,[67] X. Sun,[33a] J. E. Sundermann,[48] K. Suruliz,[140] G. Susinno,[37a,37b] M. R. Sutton,[150] Y. Suzuki,[65] M. Svatos,[126] S. Swedish,[169] M. Swiatlowski,[144] I. Sykora,[145a] T. Sykora,[128] D. Ta,[89] K. Tackmann,[42] J. Taenzer,[159] A. Taffard,[164] R. Tafirout,[160a] N. Taiblum,[154] Y. Takahashi,[102] H. Takai,[25] R. Takashima,[68] H. Takeda,[66] T. Takeshita,[141] Y. Takubo,[65] M. Talby,[84] A. A. Talyshev,[108,s] J. Y. C. Tam,[175] K. G. Tan,[87] J. Tanaka,[156] R. Tanaka,[116] S. Tanaka,[132] S. Tanaka,[65] A. J. Tanasijczuk,[143] K. Tani,[66] N. Tannoury,[21] S. Tapprogge,[82] S. Tarem,[153] F. Tarrade,[29] G. F. Tartarelli,[90a] P. Tas,[128] M. Tasevsky,[126] T. Tashiro,[67] E. Tassi,[37a,37b] A. Tavares Delgado,[125a,125b] Y. Tayalati,[136d] F. E. Taylor,[93] G. N. Taylor,[87] W. Taylor,[160b] F. A. Teischinger,[30] M. Teixeira Dias Castanheira,[75] P. Teixeira-Dias,[76] K. K. Temming,[48] H. Ten Kate,[30] P. K. Teng,[152] J. J. Teoh,[117] S. Terada,[65] K. Terashi,[156] J. Terron,[81] S. Terzo,[100] M. Testa,[47] R. J. Teuscher,[159,i] J. Therhaag,[21] T. Theveneaux-Pelzer,[34] J. P. Thomas,[18] J. Thomas-Wilsker,[76] E. N. Thompson,[35] P. D. Thompson,[18] P. D. Thompson,[159] A. S. Thompson,[53] L. A. Thomsen,[36] E. Thomson,[121] M. Thomson,[28] W. M. Thong,[87] R. P. Thun,[88,a] F. Tian,[35] M. J. Tibbetts,[15] V. O. Tikhomirov,[95,gg] Yu. A. Tikhonov,[108,s] S. Timoshenko,[97] E. Tiouchichine,[84] P. Tipton,[177] S. Tisserant,[84] T. Todorov,[5] S. Todorova-Nova,[128] B. Toggerson,[7] J. Tojo,[69] S. Tokár,[145a] K. Tokushuku,[65] K. Tollefson,[89] L. Tomlinson,[83] M. Tomoto,[102] L. Tompkins,[31] K. Toms,[104] N. D. Topilin,[64] E. Torrence,[115] H. Torres,[143] E. Torró Pastor,[168] J. Toth,[84,hh] F. Touchard,[84] D. R. Tovey,[140] H. L. Tran,[116] T. Trefzger,[175] L. Tremblet,[30] A. Tricoli,[30] I. M. Trigger,[160a] S. Trincaz-Duvoid,[79] M. F. Tripiana,[70] N. Triplett,[25] W. Trischuk,[159] B. Trocmé,[55] C. Troncon,[90a] M. Trottier-McDonald,[143] M. Trovatelli,[135a,135b] P. True,[89] M. Trzebinski,[39] A. Trzupek,[39] C. Tsarouchas,[30] J. C-L. Tseng,[119] P. V. Tsiareshka,[91] D. Tsionou,[137] G. Tsipolitis,[10] N. Tsirintanis,[9] S. Tsiskaridze,[12] V. Tsiskaridze,[48] E. G. Tskhadadze,[51a] I. I. Tsukerman,[96] V. Tsulaia,[15] S. Tsuno,[65] D. Tsybychev,[149] A. Tudorache,[26a] V. Tudorache,[26a] A. N. Tuna,[121] S. A. Tupputi,[20a,20b] S. Turchikhin,[98,ff] D. Turecek,[127] I. Turk Cakir,[4d] R. Turra,[90a,90b] P. M. Tuts,[35] A. Tykhonov,[74] M. Tylmad,[147a,147b] M. Tyndel,[130] K. Uchida,[21] I. Ueda,[156] R. Ueno,[29] M. Ughetto,[84] M. Ugland,[14] M. Uhlenbrock,[21] F. Ukegawa,[161] G. Unal,[30] A. Undrus,[25] G. Unel,[164] F. C. Ungaro,[48] Y. Unno,[65] D. Urbaniec,[35] P. Urquijo,[87] G. Usai,[8] A. Usanova,[61] L. Vacavant,[84] V. Vacek,[127] B. Vachon,[86] N. Valencic,[106] S. Valentinetti,[20a,20b] A. Valero,[168] L. Valery,[34] S. Valkar,[128] E. Valladolid Gallego,[168] S. Vallecorsa,[49] J. A. Valls Ferrer,[168] P. C. Van Der Deijl,[106] R. van der Geer,[106] H. van der Graaf,[106] R. Van Der Leeuw,[106] D. van der Ster,[30] N. van Eldik,[30] P. van Gemmeren,[6] J. Van Nieuwkoop,[143] I. van Vulpen,[106] M. C. van Woerden,[30] M. Vanadia,[133a,133b] W. Vandelli,[30] R. Vanguri,[121] A. Vaniachine,[6] P. Vankov,[42] F. Vannucci,[79] G. Vardanyan,[178] R. Vari,[133a] E. W. Varnes,[7] T. Varol,[85] D. Varouchas,[79] A. Vartapetian,[8] K. E. Varvell,[151] F. Vazeille,[34] T. Vazquez Schroeder,[54] J. Veatch,[7] F. Veloso,[125a,125c] S. Veneziano,[133a] A. Ventura,[72a,72b] D. Ventura,[85] M. Venturi,[170] N. Venturi,[159] A. Venturini,[23] V. Vercesi,[120a] M. Verducci,[139] W. Verkerke,[106] J. C. Vermeulen,[106] A. Vest,[44]

M. C. Vetterli,[143,e] O. Viazlo,[80] I. Vichou,[166] T. Vickey,[146c,ii] O. E. Vickey Boeriu,[146c] G. H. A. Viehhauser,[119] S. Viel,[169] R. Vigne,[30] M. Villa,[20a,20b] M. Villaplana Perez,[90a,90b] E. Vilucchi,[47] M. G. Vincter,[29] V. B. Vinogradov,[64] J. Virzi,[15] I. Vivarelli,[150] F. Vives Vaque,[3] S. Vlachos,[10] D. Vladoiu,[99] M. Vlasak,[127] A. Vogel,[21] M. Vogel,[32a] P. Vokac,[127] G. Volpi,[123a,123b] M. Volpi,[87] H. von der Schmitt,[100] H. von Radziewski,[48] E. von Toerne,[21] V. Vorobel,[128] K. Vorobev,[97] M. Vos,[168] R. Voss,[30] J. H. Vossebeld,[73] N. Vranjes,[137] M. Vranjes Milosavljevic,[106] V. Vrba,[126] M. Vreeswijk,[106] T. Vu Anh,[48] R. Vuillermet,[30] I. Vukotic,[31] Z. Vykydal,[127] P. Wagner,[21] W. Wagner,[176] H. Wahlberg,[70] S. Wahrmund,[44] J. Wakabayashi,[102] J. Walder,[71] R. Walker,[99] W. Walkowiak,[142] R. Wall,[177] P. Waller,[73] B. Walsh,[177] C. Wang,[152,jj] C. Wang,[45] F. Wang,[174] H. Wang,[15] H. Wang,[40] J. Wang,[42] J. Wang,[33a] K. Wang,[86] R. Wang,[104] S. M. Wang,[152] T. Wang,[21] X. Wang,[177] C. Wanotayaroj,[115] A. Warburton,[86] C. P. Ward,[28] D. R. Wardrope,[77] M. Warsinsky,[48] A. Washbrook,[46] C. Wasicki,[42] I. Watanabe,[66] P. M. Watkins,[18] A. T. Watson,[18] I. J. Watson,[151] M. F. Watson,[18] G. Watts,[139] S. Watts,[83] B. M. Waugh,[77] S. Webb,[83] M. S. Weber,[17] S. W. Weber,[175] J. S. Webster,[31] A. R. Weidberg,[119] P. Weigell,[100] B. Weinert,[60] J. Weingarten,[54] C. Weiser,[48] H. Weits,[106] P. S. Wells,[30] T. Wenaus,[25] D. Wendland,[16] Z. Weng,[152,ee] T. Wengler,[30] S. Wenig,[30] N. Wermes,[21] M. Werner,[48] P. Werner,[30] M. Wessels,[58a] J. Wetter,[162] K. Whalen,[29] A. White,[8] M. J. White,[1] R. White,[32b] S. White,[123a,123b] D. Whiteson,[164] D. Wicke,[176] F. J. Wickens,[130] W. Wiedenmann,[174] M. Wielers,[130] P. Wienemann,[21] C. Wiglesworth,[36] L. A. M. Wiik-Fuchs,[21] P. A. Wijeratne,[77] A. Wildauer,[100] M. A. Wildt,[42,kk] H. G. Wilkens,[30] J. Z. Will,[99] H. H. Williams,[121] S. Williams,[28] C. Willis,[89] S. Willocq,[85] A. Wilson,[88] J. A. Wilson,[18] I. Wingerter-Seez,[5] F. Winklmeier,[115] B. T. Winter,[21] M. Wittgen,[144] T. Wittig,[43] J. Wittkowski,[99] S. J. Wollstadt,[82] M. W. Wolter,[39] H. Wolters,[125a,125c] B. K. Wosiek,[39] J. Wotschack,[30] M. J. Woudstra,[83] K. W. Wozniak,[39] M. Wright,[53] M. Wu,[55] S. L. Wu,[174] X. Wu,[49] Y. Wu,[88] E. Wulf,[35] T. R. Wyatt,[83] B. M. Wynne,[46] S. Xella,[36] M. Xiao,[137] D. Xu,[33a] L. Xu,[33b,ll] B. Yabsley,[151] S. Yacoob,[146b,mm] M. Yamada,[65] H. Yamaguchi,[156] Y. Yamaguchi,[156] A. Yamamoto,[65] K. Yamamoto,[63] S. Yamamoto,[156] T. Yamamura,[156] T. Yamanaka,[156] K. Yamauchi,[102] Y. Yamazaki,[66] Z. Yan,[22] H. Yang,[33e] H. Yang,[174] U. K. Yang,[83] Y. Yang,[110] S. Yanush,[92] L. Yao,[33a] W-M. Yao,[15] Y. Yasu,[65] E. Yatsenko,[42] K. H. Yau Wong,[21] J. Ye,[40] S. Ye,[25] A. L. Yen,[57] E. Yildirim,[42] M. Yilmaz,[4b] R. Yoosoofmiya,[124] K. Yorita,[172] R. Yoshida,[6] K. Yoshihara,[156] C. Young,[144] C. J. S. Young,[30] S. Youssef,[22] D. R. Yu,[15] J. Yu,[8] J. M. Yu,[88] J. Yu,[113] L. Yuan,[66] A. Yurkewicz,[107] B. Zabinski,[39] R. Zaidan,[62] A. M. Zaitsev,[129,z] A. Zaman,[149] S. Zambito,[23] L. Zanello,[133a,133b] D. Zanzi,[100] C. Zeitnitz,[176] M. Zeman,[127] A. Zemla,[38a] K. Zengel,[23] O. Zenin,[129] T. Ženiš,[145a] D. Zerwas,[116] G. Zevi della Porta,[57] D. Zhang,[88] F. Zhang,[174] H. Zhang,[89] J. Zhang,[6] L. Zhang,[152] X. Zhang,[33d] Z. Zhang,[116] Z. Zhao,[33b] A. Zhemchugov,[64] J. Zhong,[119] B. Zhou,[88] L. Zhou,[35] N. Zhou,[164] C. G. Zhu,[33d] H. Zhu,[33a] J. Zhu,[88] Y. Zhu,[33b] X. Zhuang,[33a] K. Zhukov,[95] A. Zibell,[175] D. Zieminska,[60] N. I. Zimine,[64] C. Zimmermann,[82] R. Zimmermann,[21] S. Zimmermann,[21] S. Zimmermann,[48] Z. Zinonos,[54] M. Ziolkowski,[142] G. Zobernig,[174] A. Zoccoli,[20a,20b] M. zur Nedden,[16] G. Zurzolo,[103a,103b] V. Zutshi[107] and L. Zwalinski[30]

(ATLAS Collaboration)

[1]*Department of Physics, University of Adelaide, Adelaide, Australia*
[2]*Physics Department, SUNY Albany, Albany, NY, USA*
[3]*Department of Physics, University of Alberta, Edmonton AB, Canada*
[4a]*Department of Physics, Ankara University, Ankara, Turkey*
[4b]*Department of Physics, Gazi University, Ankara, Turkey*
[4c]*Division of Physics, TOBB University of Economics and Technology, Ankara, Turkey*
[4d]*Turkish Atomic Energy Authority, Ankara, Turkey*
[5]*LAPP, CNRS/IN2P3 and Université de Savoie, Annecy-le-Vieux, France*
[6]*High Energy Physics Division, Argonne National Laboratory, Argonne, IL, USA*
[7]*Department of Physics, University of Arizona, Tucson, AZ, USA*
[8]*Department of Physics, The University of Texas at Arlington, Arlington, TX, USA*
[9]*Physics Department, University of Athens, Athens, Greece*
[10]*Physics Department, National Technical University of Athens, Zografou, Greece*
[11]*Institute of Physics, Azerbaijan Academy of Sciences, Baku, Azerbaijan*
[12]*Institut de Física d'Altes Energies and Departament de Física de la Universitat Autònoma de Barcelona, Barcelona, Spain*
[13a]*Institute of Physics, University of Belgrade, Belgrade, Serbia*
[13b]*Vinca Institute of Nuclear Sciences, University of Belgrade, Belgrade, Serbia*
[14]*Department for Physics and Technology, University of Bergen, Bergen, Norway*
[15]*Physics Division, Lawrence Berkeley National Laboratory and University of California, Berkeley, CA, USA*
[16]*Department of Physics, Humboldt University, Berlin, Germany*

[17]Albert Einstein Center for Fundamental Physics and Laboratory for High Energy Physics, University of Bern, Bern, Switzerland
[18]School of Physics and Astronomy, University of Birmingham, Birmingham, United Kingdom
[19a]Department of Physics, Bogazici University, Istanbul, Turkey
[19b]Department of Physics, Dogus University, Istanbul, Turkey
[19c]Department of Physics Engineering, Gaziantep University, Gaziantep, Turkey
[20a]INFN Sezione di Bologna, Italy
[20b]Dipartimento di Fisica e Astronomia, Università di Bologna, Bologna, Italy
[21]Physikalisches Institut, University of Bonn, Bonn, Germany
[22]Department of Physics, Boston University, Boston, MA, USA
[23]Department of Physics, Brandeis University, Waltham, MA, USA
[24a]Universidade Federal do Rio De Janeiro COPPE/EE/IF, Rio de Janeiro, Brazil
[24b]Federal University of Juiz de Fora (UFJF), Juiz de Fora, Brazil
[24c]Federal University of Sao Joao del Rei (UFSJ), Sao Joao del Rei, Brazil
[24d]Instituto de Fisica, Universidade de Sao Paulo, Sao Paulo, Brazil
[25]Physics Department, Brookhaven National Laboratory, Upton, NY, USA
[26a]National Institute of Physics and Nuclear Engineering, Bucharest, Romania
[26b]National Institute for Research and Development of Isotopic and Molecular Technologies, Physics Department, Cluj Napoca, Romania
[26c]University Politehnica Bucharest, Bucharest, Romania
[26d]West University in Timisoara, Timisoara, Romania
[27]Departamento de Física, Universidad de Buenos Aires, Buenos Aires, Argentina
[28]Cavendish Laboratory, University of Cambridge, Cambridge, United Kingdom
[29]Department of Physics, Carleton University, Ottawa ON, Canada
[30]CERN, Geneva, Switzerland
[31]Enrico Fermi Institute, University of Chicago, Chicago, IL, USA
[32a]Departamento de Física, Pontificia Universidad Católica de Chile, Santiago, Chile
[32b]Departamento de Física, Universidad Técnica Federico Santa María, Valparaíso, Chile
[33a]Institute of High Energy Physics, Chinese Academy of Sciences, Beijing, China
[33b]Department of Modern Physics, University of Science and Technology of China, Anhui, China
[33c]Department of Physics, Nanjing University, Jiangsu, China
[33d]School of Physics, Shandong University, Shandong, China
[33e]Physics Department, Shanghai Jiao Tong University, Shanghai, China
[34]Laboratoire de Physique Corpusculaire, Clermont Université and Université Blaise Pascal and CNRS/IN2P3, Clermont-Ferrand, France
[35]Nevis Laboratory, Columbia University, Irvington, NY, USA
[36]Niels Bohr Institute, University of Copenhagen, Kobenhavn, Denmark
[37a]INFN Gruppo Collegato di Cosenza, Laboratori Nazionali di Frascati, Italy
[37b]Dipartimento di Fisica, Università della Calabria, Rende, Italy
[38a]AGH University of Science and Technology, Faculty of Physics and Applied Computer Science, Krakow, Poland
[38b]Marian Smoluchowski Institute of Physics, Jagiellonian University, Krakow, Poland
[39]The Henryk Niewodniczanski Institute of Nuclear Physics, Polish Academy of Sciences, Krakow, Poland
[40]Physics Department, Southern Methodist University, Dallas, TX, USA
[41]Physics Department, University of Texas at Dallas, Richardson, TX, USA
[42]DESY, Hamburg and Zeuthen, Germany
[43]Institut für Experimentelle Physik IV, Technische Universität Dortmund, Dortmund, Germany
[44]Institut für Kern- und Teilchenphysik, Technische Universität Dresden, Dresden, Germany
[45]Department of Physics, Duke University, Durham, NC, USA
[46]SUPA - School of Physics and Astronomy, University of Edinburgh, Edinburgh, United Kingdom
[47]INFN Laboratori Nazionali di Frascati, Frascati, Italy
[48]Fakultät für Mathematik und Physik, Albert-Ludwigs-Universität, Freiburg, Germany
[49]Section de Physique, Université de Genève, Geneva, Switzerland
[50a]INFN Sezione di Genova, Italy
[50b]Dipartimento di Fisica, Università di Genova, Genova, Italy
[51a]E. Andronikashvili Institute of Physics, Iv. Javakhishvili Tbilisi State University, Tbilisi, Georgia
[51b]High Energy Physics Institute, Tbilisi State University, Tbilisi, Georgia
[52]II Physikalisches Institut, Justus-Liebig-Universität Giessen, Giessen, Germany
[53]SUPA - School of Physics and Astronomy, University of Glasgow, Glasgow, United Kingdom
[54]II Physikalisches Institut, Georg-August-Universität, Göttingen, Germany
[55]Laboratoire de Physique Subatomique et de Cosmologie, Université Grenoble-Alpes, CNRS/IN2P3, Grenoble, France
[56]Department of Physics, Hampton University, Hampton, VA, USA

[57]*Laboratory for Particle Physics and Cosmology, Harvard University, Cambridge, MA, USA*
[58a]*Kirchhoff-Institut für Physik, Ruprecht-Karls-Universität Heidelberg, Heidelberg, Germany*
[58b]*Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Heidelberg, Germany*
[58c]*ZITI Institut für technische Informatik, Ruprecht-Karls-Universität Heidelberg, Mannheim, Germany*
[59]*Faculty of Applied Information Science, Hiroshima Institute of Technology, Hiroshima, Japan*
[60]*Department of Physics, Indiana University, Bloomington, IN, USA*
[61]*Institut für Astro- und Teilchenphysik, Leopold-Franzens-Universität, Innsbruck, Austria*
[62]*University of Iowa, Iowa City, IA, USA*
[63]*Department of Physics and Astronomy, Iowa State University, Ames, IA, USA*
[64]*Joint Institute for Nuclear Research, JINR Dubna, Dubna, Russia*
[65]*KEK, High Energy Accelerator Research Organization, Tsukuba, Japan*
[66]*Graduate School of Science, Kobe University, Kobe, Japan*
[67]*Faculty of Science, Kyoto University, Kyoto, Japan*
[68]*Kyoto University of Education, Kyoto, Japan*
[69]*Department of Physics, Kyushu University, Fukuoka, Japan*
[70]*Instituto de Física La Plata, Universidad Nacional de La Plata and CONICET, La Plata, Argentina*
[71]*Physics Department, Lancaster University, Lancaster, United Kingdom*
[72a]*INFN Sezione di Lecce, Italy*
[72b]*Dipartimento di Matematica e Fisica, Università del Salento, Lecce, Italy*
[73]*Oliver Lodge Laboratory, University of Liverpool, Liverpool, United Kingdom*
[74]*Department of Physics, Jožef Stefan Institute and University of Ljubljana, Ljubljana, Slovenia*
[75]*School of Physics and Astronomy, Queen Mary University of London, London, United Kingdom*
[76]*Department of Physics, Royal Holloway University of London, Surrey, United Kingdom*
[77]*Department of Physics and Astronomy, University College London, London, United Kingdom*
[78]*Louisiana Tech University, Ruston, LA, USA*
[79]*Laboratoire de Physique Nucléaire et de Hautes Energies, UPMC and Université Paris-Diderot and CNRS/IN2P3, Paris, France*
[80]*Fysiska institutionen, Lunds universitet, Lund, Sweden*
[81]*Departamento de Fisica Teorica C-15, Universidad Autonoma de Madrid, Madrid, Spain*
[82]*Institut für Physik, Universität Mainz, Mainz, Germany*
[83]*School of Physics and Astronomy, University of Manchester, Manchester, United Kingdom*
[84]*CPPM, Aix-Marseille Université and CNRS/IN2P3, Marseille, France*
[85]*Department of Physics, University of Massachusetts, Amherst, MA, USA*
[86]*Department of Physics, McGill University, Montreal QC, Canada*
[87]*School of Physics, University of Melbourne, Victoria, Australia*
[88]*Department of Physics, The University of Michigan, Ann Arbor, MI, USA*
[89]*Department of Physics and Astronomy, Michigan State University, East Lansing, MI, USAAmerica*
[90a]*INFN Sezione di Milano, Italy*
[90b]*Dipartimento di Fisica, Università di Milano, Milano, Italy*
[91]*B. I. Stepanov Institute of Physics, National Academy of Sciences of Belarus, Minsk, Republic of Belarus*
[92]*National Scientific and Educational Centre for Particle and High Energy Physics, Minsk, Republic of Belarus*
[93]*Department of Physics, Massachusetts Institute of Technology, Cambridge, MA, USA*
[94]*Group of Particle Physics, University of Montreal, Montreal QC, Canada*
[95]*P. N. Lebedev Institute of Physics, Academy of Sciences, Moscow, Russia*
[96]*Institute for Theoretical and Experimental Physics (ITEP), Moscow, Russia*
[97]*Moscow Engineering and Physics Institute (MEPhI), Moscow, Russia*
[98]*D. V. Skobeltsyn Institute of Nuclear Physics, M. V. Lomonosov Moscow State University, Moscow, Russia*
[99]*Fakultät für Physik, Ludwig-Maximilians-Universität München, München, Germany*
[100]*Max-Planck-Institut für Physik (Werner-Heisenberg-Institut), München, Germany*
[101]*Nagasaki Institute of Applied Science, Nagasaki, Japan*
[102]*Graduate School of Science and Kobayashi-Maskawa Institute, Nagoya University, Nagoya, Japan*
[103a]*INFN Sezione di Napoli, Italy*
[103b]*Dipartimento di Fisica, Università di Napoli, Napoli, Italy*
[104]*Department of Physics and Astronomy, University of New Mexico, Albuquerque, NM, USA*
[105]*Institute for Mathematics, Astrophysics and Particle Physics, Radboud University Nijmegen/Nikhef, Nijmegen, Netherlands*
[106]*Nikhef National Institute for Subatomic Physics and University of Amsterdam, Amsterdam, Netherlands*
[107]*Department of Physics, Northern Illinois University, DeKalb, IL, USA*
[108]*Budker Institute of Nuclear Physics, SB RAS, Novosibirsk, Russia*
[109]*Department of Physics, New York University, New York, NY, USA*
[110]*Ohio State University, Columbus, OH, USA*
[111]*Faculty of Science, Okayama University, Okayama, Japan*

[112]*Homer L. Dodge Department of Physics and Astronomy, University of Oklahoma, Norman, OK, USA*
[113]*Department of Physics, Oklahoma State University, Stillwater, OK, USA*
[114]*Palacký University, RCPTM, Olomouc, Czech Republic*
[115]*Center for High Energy Physics, University of Oregon, Eugene, OR, USA*
[116]*LAL, Université Paris-Sud and CNRS/IN2P3, Orsay, France*
[117]*Graduate School of Science, Osaka University, Osaka, Japan*
[118]*Department of Physics, University of Oslo, Oslo, Norway*
[119]*Department of Physics, Oxford University, Oxford, United Kingdom*
[120a]*INFN Sezione di Pavia, Italy*
[120b]*Dipartimento di Fisica, Università di Pavia, Pavia, Italy*
[121]*Department of Physics, University of Pennsylvania, Philadelphia, PA, USA*
[122]*Petersburg Nuclear Physics Institute, Gatchina, Russia*
[123a]*INFN Sezione di Pisa, Italy*
[123b]*Dipartimento di Fisica E. Fermi, Università di Pisa, Pisa, Italy*
[124]*Department of Physics and Astronomy, University of Pittsburgh, Pittsburgh, PA, USA*
[125a]*Laboratorio de Instrumentacao e Fisica Experimental de Particulas - LIP, Lisboa, Portugal*
[125b]*Faculdade de Ciências, Universidade de Lisboa, Lisboa, Portugal*
[125c]*Department of Physics, University of Coimbra, Coimbra, Portugal*
[125d]*Centro de Física Nuclear da Universidade de Lisboa, Lisboa, Portugal*
[125e]*Departamento de Fisica, Universidade do Minho, Braga, Portugal*
[125f]*Departamento de Fisica Teorica y del Cosmos and CAFPE, Universidad de Granada, Granada (Spain), Portugal*
[125g]*Dep Fisica and CEFITEC of Faculdade de Ciencias e Tecnologia, Universidade Nova de Lisboa, Caparica, Portugal*
[126]*Institute of Physics, Academy of Sciences of the Czech Republic, Praha, Czech Republic*
[127]*Czech Technical University in Prague, Praha, Czech Republic*
[128]*Faculty of Mathematics and Physics, Charles University in Prague, Praha, Czech Republic*
[129]*State Research Center Institute for High Energy Physics, Protvino, Russia*
[130]*Particle Physics Department, Rutherford Appleton Laboratory, Didcot, United Kingdom*
[131]*Physics Department, University of Regina, Regina SK, Canada*
[132]*Ritsumeikan University, Kusatsu, Shiga, Japan*
[133a]*INFN Sezione di Roma, Italy*
[133b]*Dipartimento di Fisica, Sapienza Università di Roma, Roma, Italy*
[134a]*INFN Sezione di Roma Tor Vergata, Italy*
[134b]*Dipartimento di Fisica, Università di Roma Tor Vergata, Roma, Italy*
[135a]*INFN Sezione di Roma Tre, Italy*
[135b]*Dipartimento di Matematica e Fisica, Università Roma Tre, Roma, Italy*
[136a]*Faculté des Sciences Ain Chock, Réseau Universitaire de Physique des Hautes Energies - Université Hassan II, Casablanca, Morocco*
[136b]*Centre National de l'Energie des Sciences Techniques Nucleaires, Rabat, Morocco*
[136c]*Faculté des Sciences Semlalia, Université Cadi Ayyad, LPHEA-Marrakech, Morocco*
[136d]*Faculté des Sciences, Université Mohamed Premier and LPTPM, Oujda, Morocco*
[136e]*Faculté des sciences, Université Mohammed V-Agdal, Rabat, Morocco*
[137]*DSM/IRFU (Institut de Recherches sur les Lois Fondamentales de l'Univers), CEA Saclay (Commissariat à l'Energie Atomique et aux Energies Alternatives), Gif-sur-Yvette, France*
[138]*Santa Cruz Institute for Particle Physics, University of California Santa Cruz, Santa Cruz, CA, USA*
[139]*Department of Physics, University of Washington, Seattle, WA, USA*
[140]*Department of Physics and Astronomy, University of Sheffield, Sheffield, United Kingdom*
[141]*Department of Physics, Shinshu University, Nagano, Japan*
[142]*Fachbereich Physik, Universität Siegen, Siegen, Germany*
[143]*Department of Physics, Simon Fraser University, Burnaby BC, Canada*
[144]*SLAC National Accelerator Laboratory, Stanford, CA, USA*
[145a]*Faculty of Mathematics, Physics & Informatics, Comenius University, Bratislava, Slovak Republic*
[145b]*Department of Subnuclear Physics, Institute of Experimental Physics of the Slovak Academy of Sciences, Kosice, Slovak Republic*
[146a]*Department of Physics, University of Cape Town, Cape Town, South Africa*
[146b]*Department of Physics, University of Johannesburg, Johannesburg, South Africa*
[146c]*School of Physics, University of the Witwatersrand, Johannesburg, South Africa*
[147a]*Department of Physics, Stockholm University, Sweden*
[147b]*The Oskar Klein Centre, Stockholm, Sweden*
[148]*Physics Department, Royal Institute of Technology, Stockholm, Sweden*
[149]*Departments of Physics & Astronomy and Chemistry, Stony Brook University, Stony Brook, NY, USA*
[150]*Department of Physics and Astronomy, University of Sussex, Brighton, United Kingdom*

[151]*School of Physics, University of Sydney, Sydney, Australia*
[152]*Institute of Physics, Academia Sinica, Taipei, Taiwan*
[153]*Department of Physics, Technion: Israel Institute of Technology, Haifa, Israel*
[154]*Raymond and Beverly Sackler School of Physics and Astronomy, Tel Aviv University, Tel Aviv, Israel*
[155]*Department of Physics, Aristotle University of Thessaloniki, Thessaloniki, Greece*
[156]*International Center for Elementary Particle Physics and Department of Physics, The University of Tokyo, Tokyo, Japan*
[157]*Graduate School of Science and Technology, Tokyo Metropolitan University, Tokyo, Japan*
[158]*Department of Physics, Tokyo Institute of Technology, Tokyo, Japan*
[159]*Department of Physics, University of Toronto, Toronto ON, Canada*
[160a]*TRIUMF, Vancouver BC, Canada*
[160b]*Department of Physics and Astronomy, York University, Toronto ON, Canada*
[161]*Faculty of Pure and Applied Sciences, University of Tsukuba, Tsukuba, Japan*
[162]*Department of Physics and Astronomy, Tufts University, Medford, MA, USA*
[163]*Centro de Investigaciones, Universidad Antonio Narino, Bogota, Colombia*
[164]*Department of Physics and Astronomy, University of California Irvine, Irvine, CA, USA*
[165a]*INFN Gruppo Collegato di Udine, Sezione di Trieste, Udine, Italy*
[165b]*ICTP, Trieste, Italy*
[165c]*Dipartimento di Chimica, Fisica e Ambiente, Università di Udine, Udine, Italy*
[166]*Department of Physics, University of Illinois, Urbana, IL, USA*
[167]*Department of Physics and Astronomy, University of Uppsala, Uppsala, Sweden*
[168]*Instituto de Física Corpuscular (IFIC) and Departamento de Física Atómica, Molecular y Nuclear and Departamento de Ingeniería Electrónica and Instituto de Microelectrónica de Barcelona (IMB-CNM), University of Valencia and CSIC, Valencia, Spain*
[169]*Department of Physics, University of British Columbia, Vancouver BC, Canada*
[170]*Department of Physics and Astronomy, University of Victoria, Victoria BC, Canada*
[171]*Department of Physics, University of Warwick, Coventry, United Kingdom*
[172]*Waseda University, Tokyo, Japan*
[173]*Department of Particle Physics, The Weizmann Institute of Science, Rehovot, Israel*
[174]*Department of Physics, University of Wisconsin, Madison, WI, USA*
[175]*Fakultät für Physik und Astronomie, Julius-Maximilians-Universität, Würzburg, Germany*
[176]*Fachbereich C Physik, Bergische Universität Wuppertal, Wuppertal, Germany*
[177]*Department of Physics, Yale University, New Haven, CT, USA*
[178]*Yerevan Physics Institute, Yerevan, Armenia*
[179]*Centre de Calcul de l'Institut National de Physique Nucléaire et de Physique des Particules (IN2P3), Villeurbanne, France*

[a]Deceased.
[b]Also at Department of Physics, King's College London, London, United Kingdom.
[c]Also at Institute of Physics, Azerbaijan Academy of Sciences, Baku, Azerbaijan.
[d]Also at Particle Physics Department, Rutherford Appleton Laboratory, Didcot, United Kingdom.
[e]Also at TRIUMF, Vancouver, BC, Canada.
[f]Also at Department of Physics, California State University, Fresno, CA, USA.
[g]Also at CPPM, Aix-Marseille Université and CNRS/IN2P3, Marseille, France.
[h]Also at Università di Napoli Parthenope, Napoli, Italy.
[i]Also at Institute of Particle Physics (IPP), Canada.
[j]Also at Department of Physics, St. Petersburg State Polytechnical University, St. Petersburg, Russia.
[k]Also at Chinese University of Hong Kong, China.
[l]Also at Department of Financial and Management Engineering, University of the Aegean, Chios, Greece.
[m]Also at Louisiana Tech University, Ruston, LA, USA.
[n]Also at Institucio Catalana de Recerca i Estudis Avancats, ICREA, Barcelona, Spain.
[o]Also at Institute of Theoretical Physics, Ilia State University, Tbilisi, Georgia.
[p]Also at CERN, Geneva, Switzerland.
[q]Also at Ochadai Academic Production, Ochanomizu University, Tokyo, Japan.
[r]Also at Manhattan College, New York, NY, USA.
[s]Also at Novosibirsk State University, Novosibirsk, Russia.
[t]Also at Institute of Physics, Academia Sinica, Taipei, Taiwan.
[u]Also at LAL, Université Paris-Sud and CNRS/IN2P3, Orsay, France.
[v]Also at Academia Sinica Grid Computing, Institute of Physics, Academia Sinica, Taipei, Taiwan.
[w]Also at Laboratoire de Physique Nucléaire et de Hautes Energies, UPMC and Université Paris-Diderot and CNRS/IN2P3, Paris, France.
[x]Also at School of Physical Sciences, National Institute of Science Education and Research, Bhubaneswar, India.
[y]Also at Dipartimento di Fisica, Sapienza Università di Roma, Roma, Italy.

[z]Also at Moscow Institute of Physics and Technology State University, Dolgoprudny, Russia.
[aa]Also at Department of Physics, The University of Texas at Austin, Austin, TX, USA.
[bb]Also at Section de Physique, Université de Genève, Geneva, Switzerland.
[cc]Also at International School for Advanced Studies (SISSA), Trieste, Italy.
[dd]Also at Department of Physics and Astronomy, University of South Carolina, Columbia, SC, USA.
[ee]Also at School of Physics and Engineering, Sun Yat-sen University, Guangzhou, China.
[ff]Also at Faculty of Physics, M.V. Lomonosov Moscow State University, Moscow, Russia.
[gg]Also at Moscow Engineering and Physics Institute (MEPhI), Moscow, Russia.
[hh]Also at Institute for Particle and Nuclear Physics, Wigner Research Centre for Physics, Budapest, Hungary.
[ii]Also at Department of Physics, Oxford University, Oxford, United Kingdom.
[jj]Also at Department of Physics, Nanjing University, Jiangsu, China.
[kk]Also at Institut für Experimentalphysik, Universität Hamburg, Hamburg, Germany.
[ll]Also at Department of Physics, The University of Michigan, Ann Arbor, MI, USA.
[mm]Also at Discipline of Physics, University of KwaZulu-Natal, Durban, South Africa.